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Fire Ecology of the Forest Habitat Types of Northern Idaho

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Research Summary

This report summarizes available information on fire as an ecological factor for forest habitat and community types in northern Idaho. Habitat and community types are assigned to fire groups based on fire regimes and potential forest stand development after fire.

An introductory section discusses relationships of major species (tree, shrub, herb, and animals) to fire, general considerations for fire management, and the ecology of persistent seral communities in northern Idaho. For each fire group, the authors discuss (1) vegetation, (2) forest fuels, (3) the natural role of fire, (4) potential patterns of forest stand development after fire, and (5) fire management considerations.

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Introduction

Many of the earliest written descriptions of the forests of northern Idaho (for example, Leiberg 1899a,b; Mullan 1863) included accounts of widespread fire. Biological records of fire (charcoal in bogs, fire scars on trees) indicate that fire has influenced the forests of the Northern Rocky Mountains for many centuries, probably for millennia (Roe and others 1971; Shiplett and Neuenschwander 1994; Wellner 1970a). A 1931 report from the Clearwater National Forest estimated that 67 percent of the forest area had burned in the 72 years between 1860 and 1931, most of it in 4 very severe fire years: 1888, 1889, 1910, and 1919 (Anonymous 1931). Pyne (1982) described the fires of 1910, 1919, and 1934, during which millions of acres of forest in Idaho and Montana burned, bringing national attention to the region.

Scientific investigation of fire in northern Idaho began in the 1920's with the inquiries of H. T. Gisborne at the Priest River Experimental Forest. Investigations continued through the subsequent decades with research by H. R. Flint, G. L. Hayes, G. J. Jemison, J. A. Larsen, C. Wellner, and many others (Hardy 1983). This report has been prepared to promote understanding of fire's complex role in the forests of northern Idaho. It summarizes research from northern Idaho concerning fire regime (patterns of fire frequency, severity, and size) and succession in times prior to settlement by European Americans ("presettlement" times). Specifically, the report covers the Clearwater National Forest, the Idaho Panhandle National Forests (Coeur d'Alene, Kaniksu, and St. Joe), and the Nez Perce National Forest.

In this report, the habitat types, community types, and phases described by Cooper and others (1991) are assigned to nine "fire groups." A fire group is a cluster of habitat types within a given geographic area; all habitat types in a fire group have similar presettlement fire regimes, similar response of dominant tree species to fire, and similar successional patterns. Fire groups are described to help managers understand broad patterns in the fire ecology of northern Idaho's forests. Each habitat type, community type, or phase is assigned to one fire group (table 1). Habitat types are designated in the standard format of "series/type-phase," in which "series" designates the potential climax dominant tree; "type" designates a definitive undergrowth species, and "phase" provides a further subdivision where needed. Appendix A lists the complete names of northern Idaho's habitat and cover types and phases, identifying the fire group for each. Appendix B lists additional incidental or rare habitat types (from Cooper and others 1991, appendix I) and the fire group for each.

This report is the sixth in a series of reports on fire ecology in the Northern and Intermountain Regions of the Forest Service, U.S. Department of Agriculture. Other reports in the series describe fire groups for eastern and western Montana (Fischer and Clayton 1983; Fischer and Bradley 1987), central Idaho (Crane and Fischer 1986), eastern Idaho and western Wyoming (Bradley and others 1992a), and Utah (Bradley and others 1992b). Correspondence among fire groups from different geographic areas is shown in appendix C.

The basis for fire group classification is the same for all geographic areas (fire regime, autecology of tree species, and successional pattern), but the fire groups in each report are unique because of climatic, floristic, and ecological differences among areas. For example, the driest habitat types in northern Idaho are much less severe than the driest habitat types in Utah. Douglas-fir is an important species in the dry fire groups of northern Idaho (Fire Groups One and Two); where Douglas-fir is climax, it is often associated with ponderosa pine and western larch. In Utah, Douglas-fir characterizes moderate sites and is usually associated with aspen and lodgepole pine; habitat types in the Douglas-fir series are classified into Fire Groups Four and Five.

Classification of the *Pseudotsuga menziesii/Physocarpus malvaceus* (PSME/PHMA) habitat type illustrates the potential for error when applying fire regime and successional pattern information from one geographic area to another. In Montana, the PSME/PHMA habitat type has two phases, *Calamagrostis rubescens* (CARU) and *Physocarpus malvaceus* (PHMA). Mature stands in the CARU phase are usually dominated by ponderosa pine; in the PHMA phase, mature stands are usually codominated by ponderosa pine and western larch. Detailed research on succession in PSME/PHMA (Arno and others 1985) forms the basis for classifying the phases into two different fire

Table 1—Summary of fire groups for northern Idaho. See appendix A for complete, formal list of habitat type names.

Habitat type	Habitat type	Habitat type
Fire Group Zero	**Fire Group Four**	**Fire Group Seven**
Special habitats	Dry, lower subalpine	Moderate and moist grand
	habitat types	fir habitat types
Fire Group One	ABLA/CARU[b]	ABGR/ASCA-ASCA[d]
Warm, dry	ABLA/VAGL[b]	ABGR/ASCA-MEFE[d]
Douglas-fir and	ABLA/XETE-COOC[b]	ABGR/ASCA-TABR[d]
ponderosa pine	ABLA/XETE-LUHI[b]	ABGR/CLUN-CLUN[a]
habitat types	ABLA/XETE-VAGL[b]	ABGR/CLUN-MEFE[b]
PIPO/AGSP	ABLA/XETE-VASC[b]	ABGR/CLUN-PHMA[a,e]
PIPO/FEID	TSME/XETE-LUHI	ABGR/CLUN-TABR
PIPO/SYAL	TSME/XETE-VAGL[b]	ABGR/CLUN-XETE[b,c]
PSME/AGSP	TSME/XETE-VASC[b]	ABGR/LIBO-LIBO[e]
PSME/FEID		ABGR/LIBO-XETE[b,c]
PSME/SPBE	**Fire Group Five**	ABGR/SETR[d]
PSME/SYAL	Moist, lower subalpine	ABGR/VAGL[b,c]
	habitat types	ABGR/XETE-COOC[b,c]
Fire Group Two	ABLA/CACA-CACA[b]	ABGR/XETE-VAGL[b,c]
Warm, dry to	ABLA/CACA-LEGL[b]	
moderate Douglas-fir,	ABLA/CACA-LICA	**Fire Group Eight**
grand fir, and	ABLA/CACA-VACA[b]	Moderate and moist
ponderosa pine	ABLA/CLUN-CLUN[b]	western hemlock and
habitat types	ABLA/CLUN-MEFE[b]	western redcedar
ABGR/PHMA-COOC[a]	ABLA/CLUN-XETE[b]	habitat types
ABGR/PHMA-PHMA[a]	ABLA/MEFE-COOC[b]	THPL/ASCA-ASCA[a,d]
ABGR/SPBE[a]	ABLA/MEFE-LUHI	THPL/ASCA-MEFE[b,d]
PIPO/PHMA[a]	ABLA/MEFE-VASC[b]	THPL/ASCA-TABR[d]
PSME/CAGE	ABLA/MEFE-XETE[b]	THPL/CLUN-CLUN[a]
PSME/CARU-ARUV[b]	ABLA/STAM-LICA[b,d]	THPL/CLUN-MEFE[a,b]
PSME/CARU-CARU	ABLA/STAM-MEFE[d]	THPL/CLUN-TABR
PSME/PHMA-PHMA[a]	TSHE/MEFE	THPL/CLUN-XETE
PSME/PHMA-SMST[a]	TSME/CLUN-MEFE[b]	THPL/GYDR
PSME/VACA[b]	TSME/CLUN-XETE[b]	TSHE/ASCA-ARNU
PSME/VAGL[b,c]	TSME/MEFE-LUHI	TSHE/ASCA-ASCA
	TSME/MEFE-XETE[b]	TSHE/ASCA-MEFE
Fire Group Three	TSME/STAM-LUHI	TSHE/CLUN-ARNU
Habitat and community	TSME/STAM-MEFE[d]	TSHE/CLUN-CLUN
types dominated by		TSHE/CLUN-MEFE[b]
persistent lodgepole	**Fire Group Six**	TSHE/CLUN-XETE[b]
pine	Upper subalpine	TSHE/GYDR
ABLA/VACA	habitat types	
ABLA/VASC	ABLA/LUHI	**Fire Group Nine**
PICO/VACA	LALY-ABLA	Very moist western
PICO/VASC	PIAL-ABLA	redcedar habitat types
PICO/XETE	TSME/LUHI	THPL/ADPE
		THPL/ATFI-ADPE
		THPL/ATFI-ATFI
		THPL/OPHO

[a]Likely to be maintained as persistent shrubfields by frequent severe fires.
[b]Early succession may be dominated by lodgepole pine, which is later replaced by more shade-tolerant species.
[c]Fire regime and fire ecology likely to resemble that of Group Four if area is bordered by subalpine habitat types.
[d]May be in Grand Fir Mosaic; see table 29.
[e]Fire regime and fire ecology likely to resemble that of Group Two if area is bordered by warm, dry habitat types.

groups in Montana (Groups Four and Six) (Fischer and Bradley 1987).

The PSME/PHMA habitat type also has two phases in northern Idaho, but the PHMA phase is the drier one; the *Smilacina stellata* (SMST) phase is more moist. Cooper and others (1991) commented that mature stands in the PHMA phase are usually dominated by ponderosa pine; ponderosa pine and western larch usually codominate mature stands in the SMST phase. This suggests that the dominant tree species in the PSME/PHMA-PHMA phase differ between the two geographic areas. Research describing specific successional patterns for the phases of PSME/PHMA in northern Idaho is not available. Since the PSME/PHMA habitat type often occurs in small stands, especially in the Idaho Panhandle National Forests, variation attributable to phase may be less important than variation due to influences of neighboring stands. For these reasons, the phases of PSME/PHMA are classified into a single fire group in northern Idaho (Fire Group Two); possible variation is described within that group.

The description of fire ecology in this report is offered as a general guide. Since fire regime depends partly on vegetation, it can be linked to habitat type and therefore to fire group; however, it is also strongly influenced by other factors. The influence of Native American fire use in northern Idaho is not well known (Barrett 1982; Zack and Morgan 1994b). In western Montana, areas receiving heavy use by Native Americans had more frequent fires than less-used areas (Barrett and Arno 1982). Stand development after fire also depends on previous fire history, preburn and neighboring vegetation, behavior and size of the fire, topography, climate and soil, disease history, and chance (Agee 1993; Smith 1994; Steele and others 1986; Zack and Morgan 1994b). Thus, postfire succession is not deterministic (Christensen 1988); a stand can follow one of several successional pathways after fire, and most fires produce variation in fire severity and response within stands.

The effects of neighboring vegetation on fire regime are especially important for small, isolated stands. Habitat types that are uncommon in northern Idaho have been difficult to classify in this report. We provide some ecological information concerning these habitat types from locations where they are more abundant, but managers must integrate that information with knowledge of the fire regime and ecology of surrounding stands.

Format

This report is patterned after fire ecology reports from Montana, Utah, western Wyoming, and other parts of Idaho. Major topics are organized as follows:

Nomenclature and Terminology—This section describes the sources used in this report for nomenclature of plants, animals, and other organisms. It also defines terms that describe silviculture, fire regimes, and fire severity.

Relationship of Major Tree Species to Fire—This section discusses each principal tree species in the northern Idaho forests with regard to its resistance and susceptibility to fire and its role as a successional component of forest communities.

Undergrowth Response to Fire—This section summarizes the effects of fire on the response of important grass, forb, and shrub species associated with the major tree species. Particular attention is given to fire-adaptive traits and survival strategies that determine whether that species' cover generally increases or decreases in the first years after fire.

Fire Effects on Animals—This section describes direct and indirect effects of fire on animals in northern Idaho.

Fire Effects and Fire Use: General Considerations—This section summarizes topics that apply to the use of fire in several or all fire groups. Emphasis is on prescribed fire planning and forest health; characteristics of fuels, including large woody debris; fire-caused tree mortality; fire's interactions with insects and diseases; considerations regarding soil, hydrology, and air quality; models of stand development after fire; and application of fire ecology at the landscape level.

Successional Communities Occurring in More than One Fire Group—Two plant communities occur in northern Idaho forests, but are not limited to a specific fire group: persistent seral shrubfields and seral lodgepole pine. Discussion of persistent seral shrubfields describes the role of fire in establishing and maintaining shrubfields in northern Idaho, and general management considerations in regard to seral shrubfields. Discussion of seral lodgepole pine describes its successional role in northern Idaho forests and general characteristics and management. Considerations unique to individual fire groups are discussed in the appropriate groups.

Fire Groups—The fire groups, and the forest habitat and cover types that comprise them, are summarized in table 1.

Fire Group Zero lists and briefly discusses habitat types of northern Idaho that are not characterized by succession to coniferous forest communities. Fire Groups One through Nine are arranged in an order similar to that used in the fire ecology reports for other areas: from the warmest, driest habitat types of low elevations, through the cold habitat types of high elevations, finally to the warm, moist habitat types

found in montane and lower elevation forests. Use of this order means that the fire groups that cover the largest acreage in northern Idaho, the expanses of land covered by grand fir, western redcedar, and western hemlock habitat types, are in Fire Groups Seven and Eight.

Each fire group description includes the following six sections:

1. Habitat types that comprise the fire group.
2. Vegetation. Climax and seral tree species are identified. Characteristic understory vegetation is described.
3. Fuels. Fuel complexes likely to be found in the fire group are described. The emphasis is on naturally occurring litter, duff, and dead, downed woody fuels. Live and standing dead fuels are also discussed. Fuel data in this report are mainly from the Sustainable Ecological Systems project in northern Idaho (Mital 1993).
4. Role of fire. This section reviews fire regime literature for the fire group. This encompasses the three aspects of fire regime, as listed by Mutch (1992): fire type and severity, fire size or area, and fire frequency. Little information on presettlement fire size is available, however. Locations of the principal fire history studies from northern Idaho are shown in figure 1. The authors define the presettlement era as ending either in the late 1800's or around 1930; data on fire return intervals span 200 to 500 years.

Fire regime descriptions are integrated with information on the ecology of important tree species, characteristics of site and climate, and fuels to describe the role of fire in shaping plant communities. Attention is given to apparent differences between presettlement and current fire regimes.

5. Forest succession. This section describes forest development following fire, as driven by climate and site (habitat type), time, fire severity, and characteristics of tree species—particularly shade tolerance and resistance to fire. Successional pathway diagrams (following Kessell and Fischer 1981) are shown for pathways well described in the literature. Successional stages are described in terms of dominant species and tree sizes, following Drury and Nisbet's (1973) use of "succession" to indicate changes in the "conspicuousness" of species rather than replacement of species over time. Since successional pathways indicate potential stand development with various fire severities at various stages of development, they can be used to assess large, uniform burns and also burns with patches of different fire severity.

Since the species composition of early successional stands is variable and influences stand composition for centuries (Agee 1993; Shiplett and Neuenschwander 1994), many fire groups have more than one successional pathway. Postfire development in a particular stand is subject to influences from other disturbances, native and exotic insects and diseases, short- and long-term climatic changes, and interactions among these forces; thus succession may follow an intermediate pathway or diverge from the patterns shown.

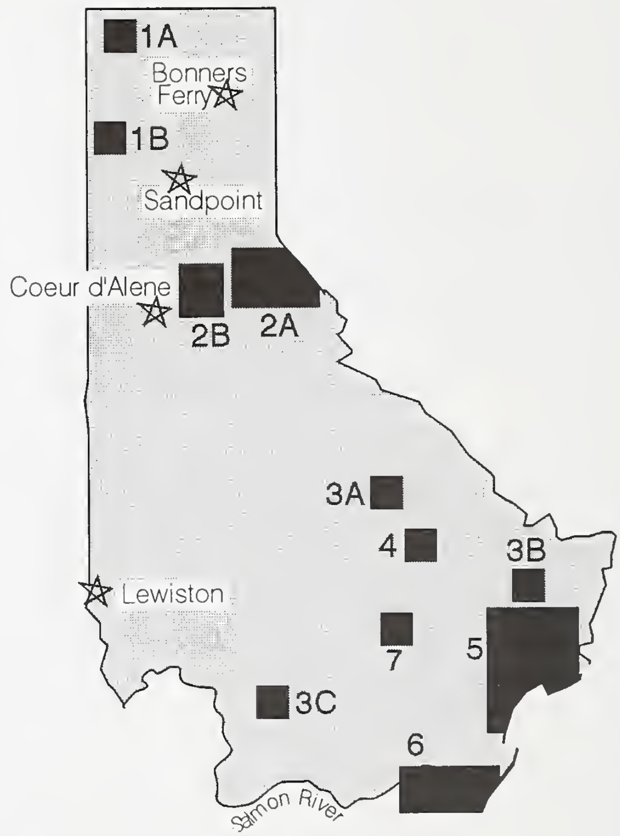

Figure 1—Northern Idaho and locations of fire history studies: (1A) north of Priest Lake and (1B) Goose Creek, Priest River Drainage, Kaniksu National Forest (Arno and Davis 1980); (2A) interior and (2B) Rathdrum Prairie vicinity, N. Fork Coeur d'Alene R. basin, Coeur d'Alene National Forest (Zack and Morgan 1994b); (3A) N. Fork, Clearwater R. drainage, Clearwater National Forest, (3B) Lochsa R. drainage, Clearwater National Forest, and (3C) S. Fork, Clearwater R. drainage, Nez Perce National Forest (Barrett 1993); (4) Cook Mountain area, Clearwater National Forest (Barrett 1982); (5) Selway-Bitterroot Wilderness, Idaho portion (Barrett and Arno 1991; Brown and others 1993, 1994); (6) River of No Return Wilderness, Salmon R. drainage, southern edge, Nez Perce National Forest (Barrett 1984); (7) Selway Ranger District, Nez Perce National Forest (Green 1994).

6. Fire management considerations. This section summarizes the use of fire ecology information in fire management plans for the fire group. Many technical aids are available for assessing forest development under different fire regimes and for estimating conditions under which prescribed fire objectives can be met. Several of these are discussed in "Fire Effects and Fire Use: General Considerations."

Knowledge of general patterns and use of technical aids can complement, but not replace, understanding of the specific dynamics occurring in a particular landscape. Hutto and others (1993) summarized the need for local expertise in protecting habitat for migratory birds, but their recommendations are appropriate for many aspects of management: "Be cautious about extrapolating results from other areas. Everything from habitat use to food requirements changes markedly from one place to another. Rely heavily on information about the natural history and ecology of the local area for management decisions."

Nomenclature and Terminology

Common names of trees and scientific names of shrubs and herbs are used throughout the text of this report. Corresponding scientific and common names are listed in appendix D. Scientific names follow Hitchcock and Cronquist (1973). A major exception is the nomenclature for genera of perennial Triticaceae. As recommended by Barkworth and Dewey (1985), *Pseudoroegneria spicata* is used for bluebunch wheatgrass, formerly called *Agropyron spicatum*. Where *Agropyron spicatum* occurs in the name of a habitat type, it has not been changed. Common names follow Hitchcock and Cronquist (1973), Patterson and others (1985), and U.S. Department of Agriculture, Soil Conservation Service (1994). Species are classified as trees or shrubs based on Little (1979). For discussion of the status of *Taxus brevifolia*, however, see "Pacific yew" under "Relationships of Major Tree Species to Fire."

In lists of habitat types and in successional pathways, species names are abbreviated using the first two letters of the genus and the first two letters of the species. The following common names and abbreviations are used for tree species:

Alpine larch, *Larix lyallii*	(LALY)
Black cottonwood, *Populus trichocarpa*	(POPTRI)
Douglas-fir, *Pseudotsuga menziesii*	(PSME)
Engelmann spruce, *Picea engelmannii*	(PIEN)
Grand fir, *Abies grandis*	(ABGR)
Lodgepole pine, *Pinus contorta*	(PICO)
Mountain hemlock, *Tsuga mertensiana*	(TSME)
Pacific yew, *Taxus brevifolia*	(TABR)
Paper birch, *Betula papyrifera*	(BEPA)
Ponderosa pine, *Pinus ponderosa*	(PIPO)
Quaking aspen, *Populus tremuloides*	(POPTRE)
Subalpine fir, *Abies lasiocarpa*	(ABLA)
Western hemlock, *Tsuga heterophylla*	(TSHE)
Western larch, *Larix occidentalis*	(LAOC)
Western redcedar, *Thuja plicata*	(THPL)
Western white pine, *Pinus monticola*	(PIMO)
Whitebark pine, *Pinus albicaulis*	(PIAL)

The complete, formal names of habitat and community types are listed at the beginning of each fire group, and a complete list is given in appendix A.

Animals, insects, and diseases are identified by both common and scientific name the first time they occur in the text; in subsequent references, only the common name is used. Nomenclature of mammal species follows Jones and others (1992). Nomenclature of insects and diseases follows Beckman and others (1994). Dwarf mistletoe species (*Arceuthobium* spp.) are referred to in most cases by genus only.

Forestry and Silvicultural Terms

The structural stage concept presented by Oliver (1981) is often used to describe forest stand development. O'Hara and others (1996) adapted this concept to forests in the Northern Rocky Mountains, including those of northern Idaho. Where sufficient information is available, we include their structural stages (table 2) in descriptions of succession.

Tree response to fire depends to some extent on tree size. The following size classes are used in this report:

Sapling	1.0-4.9	inches diameter at breast height (d.b.h.)
Pole	5.0-8.9	inches d.b.h.
Tree	9.0	inches d.b.h. and larger

Where data are available, trees are described as medium (9.0-20.9 inches d.b.h.), large (21.0-32.9 inches), and very large (33.0 inches and greater).

We use many common silvicultural terms in this report to describe stand conditions such as age, density (stocking), and species composition. These terms are used in a qualitative rather than a quantitative sense, conforming to definitions of the Society of American Foresters (1958, 1971).

Fire Return Intervals

"Mean fire return interval" is the average interval in years between fires that left evidence in a stand. Fire history investigators use fire scars as evidence of nonlethal burns; they use stand age, structure, and species composition to infer the time of stand-replacing fires. They caution that estimates of historic fire intervals are conservative because low-severity fires can affect stand development without scarring trees or inducing substantial regeneration (Arno 1976; Arno

Table 2—Forest structural stages (O'Hara and others 1996).

Structural stage	Definition	Description
Stand initiation	Following severe disturbance, growing space is occupied - typically by survivors and all species with seed source.	1 canopy stratum (broken or continuous); 1 cohort of seedlings or saplings. Grasses, forbs, and shrubs may also be present.
Stem exclusion — open canopy	New tree stems are excluded (moisture limited). Crowns are open growing, canopy broken; can be maintained by frequent underburning or other management.	1 broken canopy stratum, 1 cohort; poles or small trees.[a]
— closed canopy	New tree stems are excluded (light or moisture limited); crowns are abrading, canopy closed.	Continuous closed canopy; 1 cohort. ≥ 1 canopy strata; lower strata, if present, same age as upper strata. Poles, small, or medium trees.[a]
Understory reinitiation	Second cohort is established under older, typically seral overstory; mortality in overstory creates growing space for new trees in understory.	Broken overstory canopy; > 2 canopy strata; 2 cohorts. Overstory poles, or small or medium trees; understory seedlings, saplings, or poles.[a]
Young forest — multi strata	Large, seral overstory trees are generally absent due to harvesting or other disturbance. Several cohorts have established under influence of fires, insects and diseases, or management.	Broken overstory canopy; > 2 canopy strata; > 2 cohorts. Large trees absent in overstory; diverse horizontal and vertical distributions of trees and tree sizes. Seedlings, saplings, poles, small and medium trees.[a]
Old forest — multi strata	Multi-cohort, multistrata stand with large, old trees.	Broken overstory canopy; > 2 canopy strata; > 2 cohorts. Medium and large trees dominate overstory. Horizontal and vertical distributions of trees and tree sizes diverse.[a]
— single stratum	Single stratum stand of large, old trees. Few or no young trees in understory; parklike conditions resulting from nonlethal fire or other management.	Broken or continuous canopy of large, old trees; 1 stratum, ≥ 1 cohort; overstory of large trees. Understory trees absent, or seedlings or saplings present.[a]

[a] Grasses, forbs, and shrubs may be present in the understory.

and Sneck 1977). Within fire groups, variation in presettlement fire return intervals was caused, at least in part, by climatic and topographic factors (Arno and Davis 1980; Barrett 1982, 1984, 1993; Marshall 1928), different fire regimes in adjacent plant communities (Barrett 1982, 1993; Barrett and Arno 1991; Zack and Morgan 1994b), and variation in use by Native Americans (Barrett 1980; Robbins and Wolf 1994). Important influences since Euro-American settlement have included timber harvesting, livestock grazing, and fire exclusion.

Fire Severity

Fire severity is the degree to which a site has been altered or disrupted by fire (McPherson and others 1990). It is described either in terms of fire behavior and physical effects ("first order" effects, as used in Keane and others 1994b) or in terms of effects on the dominant vegetation. The two concepts are closely related, but they are not the same. Since studies of fire history do not have information on fire behavior, they classify fire severity in terms of long-lasting effects on the dominant vegetation—primarily fire scars and mortality (for example, Barrett and Arno 1991; Barrett and others 1991). The following criteria are the basis for describing fire severity in historic fire regimes in this report:

1. *Nonlethal burns* cause little mortality in mature trees. Often called "cool" or "low-severity" fires, these are surface or understory burns. The extent of overstory mortality included within the nonlethal category

varies from 10 to 30 percent (Brown and others 1994; Zack and Morgan 1994b). The nonlethal category may also include unburned patches (Brown and others 1994).

2. *Lethal burns*, also called "stand-replacing" burns (Barrett and Arno 1991), cause high mortality in canopy trees throughout most of the stand. Lethal fires are often crown fires, but the category also includes underburns that cause high mortality. Lethal surface burning accounts for 58 percent of the recent (1979-1990) stand-replacing fire in the Selway-Bitterroot Wilderness (Brown and others 1994). Such underburns were common in the Idaho Panhandle National Forests during the drought year 1994 as fires with short flame lengths burned through very dry duff and killed tree roots (Zack 1993). Although crowning and severe underburning are both considered "lethal," their ecological effects differ. Unlike crown fire, lethal underburning may leave dead foliage that can provide soil protection. Lethal underburns also leave more viable seed in tree canopies and leave more unburned patches than crown fires (Brown and others 1994; Romme 1993). Zack and Morgan (1994b) limited the lethal fire category to fires causing at least 90 percent mortality over 90 percent or more of the stand.

3. *Mixed-mortality burns* have varying effects on the canopy, both lethal and nonlethal, and produce irregular, patchy mosaics. Mixed-mortality burns have been described for several areas in northern Idaho (Barrett 1993; Barrett and Arno 1991; Zack and Morgan 1994b).

Physical properties of a fire, if known, are logical descriptors of fire severity. Their use is more common in fire effects and succession studies than in fire history studies. Ryan and Noste (1985) described fire severity in terms of upward and downward heat flux (fig. 2), which are somewhat independent of each other (Armour and others 1984; Stickney 1990). Flame length classes are used to describe heat flux upward from surface fuels into the standing vegetation. Depth of char (defined in table 3) is used to describe heat flux from surface fuels and duff into the soil. Depth of char classes apply to areas with relatively uniform fire severity; they can be applied over areas with variable fire severity using the stand-level classification described by Wells and others (1979) (table 4).

Few studies describe fire severity with the detail accommodated by figure 2. To roughly categorize these levels of fire severity in this report, we use the following two classes:

1. *Low-severity fire* refers to fire severity that is mostly in flame length classes 1 and 2, and with depth of char mostly in classes U and L (fig. 2). Low-severity fires burn in surface fuels, consuming only the litter, herbaceous material, and foliage and small twigs on woody undergrowth. The upper duff may be charred, but lower duff and soil are not altered. Low-severity fires may be discontinuous, producing patchy patterns. Low-severity fires kill some overstory trees of fire-sensitive species, but few of fire-resistant species. Thus, they often produce "nonlethal" burns.

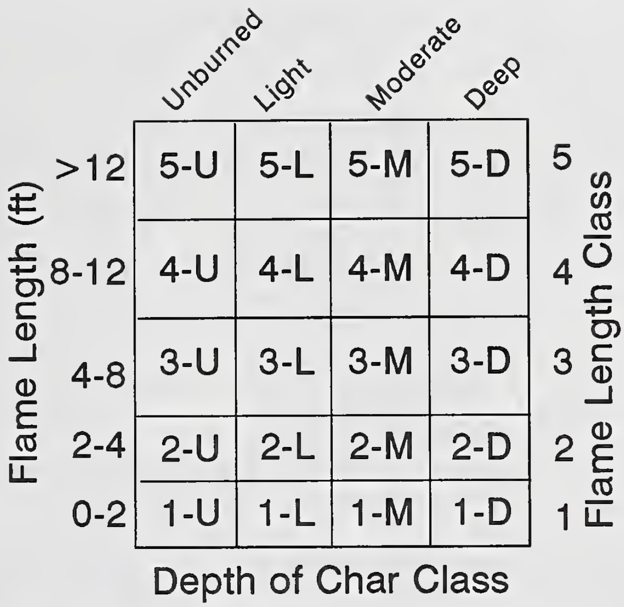

Figure 2—Two-dimensional fire severity matrix (Ryan and Noste 1985).

2. *Severe fire* describes fires with flame lengths in classes 4 and 5, especially when combined with depth of char in classes M (duff deeply charred or consumed) and D (top layer of soil visibly altered, often reddish). It also describes fires that cause char in classes M and D even with shorter flames. Severe fires are "lethal," either because they cause extensive torching or crowning in the overstory, or because the downward heat pulse girdles mature trees and kills many roots.

Use of two severity classes is obviously simplistic for describing the complexity of fire severity. We do not intend these classes to describe the full continuum of possible severities, but rather to describe likely endpoints of the continuum. A *moderate-severity* fire category has been used in some reports to describe fires that burn in surface fuels and consume upper duff, understory plants, and foliage on understory trees. Burns of moderate severity have not been well described in fire history or succession studies from northern Idaho, so the moderate-severity designation is little used in this report. Patchy, nonuniform fire behavior is better described as "*mixed-severity*," analogous to "mixed-mortality," defined above.

Table 3—Visual character of ground char from observation of depth of burn[a] (Ryan and Noste 1985).

Ground char class	Site: Timber/slash	Site: Shrub fields	Site: Grasslands
Unburned	The fire did not burn on the forest floor. Some damage may occur to vegetation due to radiated or convected heat from adjacent areas. Ten to 20 percent of the area within slash burns is commonly unburned.[b] There is a wide range in the percent of unburned area within fires in natural fuels.	See timber/slash	See timber/slash
Light ground char	Leaf litter is charred or consumed. Upper duff may be charred, but the duff layer is not altered over the entire depth. The surface generally appears black immediately after the fire. Woody debris is partially burned. Some small twigs and much of the branch wood remain. Logs are scorched or blackened but not charred. Crumbled, rotten wood is scorched to partially burned. Light ground char commonly makes up 0-100 percent of burned areas with natural fuels and 45-75 percent of slash areas.	Leaf litter is charred or consumed, and some leaf structure is still discernible. The surface is predominantly black, although some gray ash may be present immediately after the fire. Gray ash soon becomes inconspicuous. Charring may extend slightly into soil surface where leaf litter is sparse, but the mineral soil is not otherwise altered. Some leaves and small twigs remain on the plants. Burns are irregular and spotty. Less than 60 percent of the brush canopy is commonly consumed.	Litter is charred or consumed, but some plant parts are still discernible. Charring may extend slightly into the soil surface, but the mineral soil is not otherwise altered. Some plant parts may still be standing. Bases of plants are not deeply burned and are still recognizable. Surface is predominantly black immediately after the burn, but this soon becomes inconspicuous. Burns may be spotty to uniform, depending on the continuity of the grass.
Moderate ground char	Litter is consumed.[c] Duff is deeply charred or consumed but the underlying mineral soil is not visibly altered. Light-colored ash prevails immediately after the fire. Woody debris is largely consumed. Some branch wood is present, but no foliage or twigs remain. Logs are deeply charred.	Surface leaf litter is consumed. Some charred litter may remain but is sparse. Charring extends up to 0.5 inch into mineral soil but does not otherwise alter the mineral soil. Gray or white ash is conspicuous immediately after the burn, but this quickly disappears.	Litter is consumed, and the surface is covered with gray or white ash immediately after the burn. Ash soon disappears, leaving bare mineral soil. Charring extends slightly into mineral soil, but the plant parts are no longer discernible, no plant parts standing, and the bases of plants are burned to ground level.

(con.)

Table 3—Con.

Ground char class	Site: Timber/slash	Site: Shrub fields	Site: Grasslands
	Moderate ground char commonly occurs on 0-100 percent of natural burned areas and 10-75 percent on slash burns. Trees with lateral roots in the duff are often left on pedestals or topple. Burned-out stump holes are common.	Some charred stems remain on the plants, and these are generally greater than 0.25-0.50 inch in diameter. Burns are more uniform than in previous classes. Between 40 and 80 percent of the brush canopy is commonly consumed.	Plant bases are obscured in the ash immediately after burning. Burns tend to be uniform. Moderate ground char is generally limited to backing fires and fires burning during dry conditions.
Deep ground char	Litter and duff are completely consumed, and the top layer of mineral soil is visibly altered, often reddish. Structure of the surface soil may be altered. Below the colored zone 1 inch or more of the mineral soil is blackened from organic material that has been charred or deposited by heat conducted downward. Twigs and small branches are completely consumed. Few large branches may remain, but those are deeply charred. Sound logs are deeply charred, and rotten logs are completely consumed. Deep ground char occurs in scattered patches under slash concentrations or where logs or stumps produced prolonged, intense heat. Deep ground char generally covers less than 10 percent of natural and slash areas. One extreme case of 31 percent was reported in a slash burn. In extreme cases, clinkers or fused soil may be present. These are generally restricted to areas where slash was piled.	Leaf litter is completely consumed, leaving a fluffy white ash surface. All organic matter is consumed in the mineral soil to a depth of 0.5-1.0 inch. This is underlain by a zone of black organic material. Colloidal structure of the surface mineral soil may be altered. Large branches with main stems are burned, and only stubs greater than 0.5 inch in diameter remain.	Deep ground char is uncommon due to short burnout time of grasses. Surface consists of fluffy white ash immediately after the burn. This soon disappears leaving bare mineral soil. Charring extends up to 0.5 inch into soil. Soil structure is slightly altered (for consistency with other fuel types; no citations specifically mention soil alteration). Deep ground char is generally limited to situations where heavy loadings on mesic sites have burned under dry conditions and low wind.

[a]Visual characteristics were developed from other literature sources and combined for consistency; see Ryan and Noste (1985).
[b]The area coverage estimates for each of the ground char classes are ranges encountered in the literature. Obviously, any combination of depth of char classes is possible. The inclusion of these ranges points out the variability that may be encountered within a given fuel situation.
[c]Some late-season fires have been observed to spread by glowing combustion in the duff, leaving the charred remains of the litter on top of the mineral soil and ash. This should not be confused with light ground char because temperature measurements indicate a considerable heat pulse is received by the mineral soil.

Table 4—Classes for describing areas with nonuniform ground char (Wells and others 1979).

Area ground char class	Percent of area: Deeply charred[a]	Moderately charred[a]	Lightly charred[a] or unburned
Light	< 2	<15	Remainder
Moderate	2-10	>15	Remainder
Heavy	>10 and >80 percent deep or moderate		Remainder

[a]As described in table 3.

Relationships of Major Tree Species to Fire

Fire has played a major role in shaping the forests of the Western United States, including northern Idaho. Fire has, in general, favored shade-intolerant species, which tend to be more resistant to fire than shade-tolerant trees (Minore 1979). Without fire, for example, Douglas-fir and grand fir have come to dominate many sites where western white pine, western larch, and ponderosa pine were historically dominant. Many changes in forest structure and composition that have taken place in this century can be attributed to the interactions of several forces: fire exclusion, selective harvesting, intensive grazing, and the influences of insects and diseases, both native and exotic. The decline of western white pine on thousands of acres in northern Idaho is a graphic example of the combined effects of fire exclusion, selective harvesting, and an exotic disease.

This section summarizes the relative fire resistance of major tree species in northern Idaho forests. Pacific yew is included because it functions as a climax species on some sites (Crawford and Johnson 1985), even though it is usually an understory tree and often has a brushy growth form. Paper birch, quaking aspen, and black cottonwood are minor species in northern Idaho forests and are not included here. Much of the information in this section is summarized from summaries of the fire ecology of plant species contained in the Fire Effects Information System (FEIS) (Fischer 1991; Fischer and others 1996).

Alpine Larch (*Larix lyallii*)

Alpine larch is a species easily damaged by fire (table 5), but stands of alpine larch are moderately fire resistant because of their structure and location (Arno 1990). Alpine larch grows only at high elevations, inhabiting rocky sites that are generally moist and cold, where fine fuels are usually sparse and patchy. The species often grows in small groves and pioneers on rockslides and talus where moisture is available (Arno and Habeck 1972). In the lower portion of its elevational distribution, alpine larch occurs with subalpine fir, Engelmann spruce, and whitebark pine.

In areas near timberline, fire is less frequent and widespread than in contiguous forests below. Although severe fires enter alpine larch forests from lower forests, they often burn patchily and cause mixed mortality in the tree canopy (Barrett and Arno 1991). Sparse vegetation and rocky slopes curtail fire intensity. Mature alpine larches have high, open crowns but relatively thin bark; they are protected from fire more by their habitat than by physiological characteristics. Northern Idaho's severe Sundance Fire of 1967 killed most of the whitebark pine on ridgetops and much of the spruce and fir in cirques, but caused only minor damage to the isolated stands of alpine larch (Arno 1970).

Alpine larches that survive fire benefit from reduced debris. Alpine larch establishes most successfully on mineral or rocky soil, on north-facing slopes, but establishment and growth are very slow. Richards (1981) found alpine larch seedlings 16 to 25 years old that were only 8 to 16 inches tall, with 16 to 24 inch taproots. Trees do not produce ample seed until they are about 200 years old.

Alpine larch is intolerant of shade. On most sites, competitors do not grow well enough to overtop alpine larch. At relatively low elevations, however, where subalpine fir and Engelmann spruce can thrive, fire enables alpine larch to remain a major forest component (Arno 1970).

Fire Group Six describes the role of fire in alpine larch communities.

Douglas-fir (*Pseudotsuga menziesii*)

Mature Douglas-firs are fire resistant (table 5). Saplings and small poles, however, are vulnerable to surface fires because of their thin, photosynthetically active bark, low branches, resin blisters, closely spaced

Table 5—Relative fire resistance of major tree species in northern Idaho (Flint 1925). Notes in parentheses indicate fire-resistance rankings in Minore (1979) where different from Flint's evaluations. The following species were not included in either ranking: black cottonwood, Pacific yew, paper birch, quaking aspen.

Species	Thickness of bark of old trees	Root habit	Resin in old bark	Tolerance: Branch habit	Tolerance: Stand habit	Relative inflammability of foliage	Lichen growth	Degree of fire resistance
Alpine larch[a]	Thin	Deep		Open	Open			Moderate
Douglas-fir	Very thick	Deep	Moderate	Moderately low and dense	Moderate to dense	High	Heavy to medium	Very high
Engelmann spruce	Thin	Shallow	Moderate	Low and dense	Dense	Medium (High)	Heavy	Low
Grand fir	Thick	Shallow[b]	Very little	Low, dense	Dense	High (Medium)	Heavy (Medium)	Medium
Lodgepole pine	Very thin	Deep[c]	Abundant	Moderately high and open	Open	Medium	Light	Medium
Mountain hemlock	Medium	Medium	Very little	Low, dense	Dense	High	Medium to heavy	Low (Medium)
Ponderosa pine	Very thick	Deep	Abundant	Moderately high and open	Open	Medium (Low)	Medium to light	Very high
Subalpine fir	Very thin	Shallow	Moderate	Very low and dense	Moderate to dense	High	Medium to heavy	Very low
Western hemlock	Medium	Shallow	Very little	Low, dense	Dense	High	Heavy	Low
Western larch	Very thick	Deep	Very little	High, very open	Open	Low	Medium to heavy	Most resistant
Western redcedar	Thin	Shallow	Very little	Moderately low, dense	Dense	High	Heavy (Medium)	Medium
Western white pine	Medium	Medium	Abundant	High, dense	Dense	Medium	Heavy (Medium)	Medium
Whitebark pine[a]	Thin	Deep		High and open	Open		Moderate	Moderate

[a]Information taken from Arno (1990), Arno and Hoff (1990), and Lasko (1990).
[b]Grand fir roots are deeper on dry than moist sites (Foiles and others 1990).
[c]Lodgepole pine is generally deep rooted in well-drained, medium-textured soils. Root development is restricted by layers of coarse soil, impermeable layers, high water tables, or dense stand conditions (Pfister and Daubenmire 1975).

flammable needles, thin twigs, and thin bud scales. As trees mature, they develop a thick layer of insulative, corky bark that provides protection against low- to moderate-severity fires. Fire-resistant bark takes about 40 years to develop on moist sites; trees 6 inches d.b.h. have somewhat fire-resistant bark (Arno 1988). Mature Douglas-fir can survive fires that destroy the cambium in three out of four quadrants at breast height (Ryan and others 1988). The protection afforded by fire-resistant bark, however, is often offset by a tendency for shallow roots to be damaged by fire (Ryan and others 1988), growth of closely spaced branches along the bole, and "gum cracks" on the lower trunk that streak the bark with flammable resin. Resin deposits contribute to the enlargement of old fire scars during subsequent fires. Douglas-firs that survive fire often develop decay in fire-caused wounds.

A study of Douglas-fir survival after fire that included sampling in northern Idaho showed that crown scorch was the most useful predictor of mortality (Peterson and Arbaugh 1986), but many other factors were important. Crown scorch from summer fires may be more damaging than from fires late in the season.

Postfire growth of surviving Douglas-firs depends on their condition before burning and the extent of crown damage. In western Montana, Douglas-fir growth in a stagnated stand thinned by fire did not differ from growth in unthinned stands (Reinhardt and Ryan 1988a). Growth of surviving trees declines when crown scorch exceeds 50 percent (Peterson and others 1991).

Douglas-fir often grows in dense stands with horizontally and vertically continuous fuels underneath, especially if low-severity fires have been excluded for many years. Dense sapling thickets can form an almost continuous layer of flammable foliage about 10 to 26 feet aboveground. Small thickets of saplings (sometimes with dwarf mistletoe) also provide routes by which surface fires can reach the crowns of mature trees. Douglas-firs do not survive crown fire, but some individuals survive in stands where fire behavior was not uniformly severe.

Douglas-fir germinates well on ash (Fisher 1935; Hermann and Lavender 1990). Establishment is best on mineral soil and in organic seedbeds less than 2 inches thick; it may require the reduction of competing vegetation. Regeneration on burned sites is generally good in moist habitat types, where Douglas-fir is seral, and poorer where Douglas-fir is the climax species. Seedling establishment begins within a few years after fire. Regeneration on dry, south- and west-facing slopes requires shade.

The effects of fire on dry forest communities in northern Idaho, where Douglas-fir is often the climax species, are discussed in Fire Groups One and Two. Douglas-fir is an important seral species in Fire Groups Four, Seven, and Eight.

Engelmann Spruce (*Picea engelmannii*)

Engelmann spruce has low resistance to fire (table 5). Thin, resinous bark, a low-growing canopy, and dead, dry lower limbs often draped with lichens all contribute to the species' vulnerability. The shallow root system (Alexander and Shepperd 1990) is readily injured by fires that consume the duff. Deep accumulations of resinous needle litter around spruces make them particularly susceptible to cambium damage. Large old spruce trees occasionally survive one or more low-severity fires, but survivors are subject to attack by wood-destroying fungi that enter easily through fire-caused wounds. Engelmann spruce's high susceptibility to fire damage is mitigated in part by the generally cool, moist sites where it grows. Fires in moist sites are often patchy and of mixed severity, enabling some trees to survive.

Engelmann spruce germinates well on mineral soil seedbeds and on duff up to 2 inches deep; rotten wood is also a good seedbed (Fisher 1935). Seedlings are very sensitive to heat and drought. Deep ash, such as that produced by burning slash piles, inhibits regeneration. Heavy rainfall, frost, and an early-successional mat of grasses and seedlings all reduce survival. On moderate sites, spruce can become established within 5 to 10 years after fire, but 100 years or more may be needed near timberline. Spruce regeneration usually diminishes 100 to 150 years after stand establishment due to duff accumulation and competition from more shade-tolerant species.

Spruce saplings grow well in partial shade, but grow more slowly than those of many pioneer species on open sites (Alexander and Shepperd 1990). One year old seedlings are seldom over 1 inch tall, and 5 year old seedlings are often 1 to 4 inches tall. In moist subalpine stands, spruce often dominates within a few decades after fire. On drier sites, it regenerates along with other pioneer species but is overtopped early in succession. When species such as lodgepole pine begin to decline, spruce gradually becomes dominant along with shade-tolerant species.

Engelmann spruce can act as a seral or climax species in Fire Groups Four, Five, and Six (Cooper and others 1991). It has a strictly seral role in Fire Groups Seven, Eight, and Nine.

Grand Fir (*Abies grandis*)

Mature grand firs sometimes survive low-severity fires because of their moderately thick bark. However, their low and dense branching habit, highly flammable foliage, heavy lichen growth, relatively shallow roots, and dense stand habit make grand firs quite susceptible to fire injury and death (table 5). Even if mature trees survive fire, fire scarring makes them very susceptible to decay. Dormant infections of

Indian paint fungus (*Echinodontium tinctorium*) are activated by injuries, including those from fire; additional pathogens enter trees through fire-caused wounds (Filip and others 1983). Grand firs less than 4 inches d.b.h. have thin, photosynthetically active bark and so are especially susceptible to fire (Hall 1976). Grand firs are somewhat more fire resistant on dry than moist sites because they develop deep roots on dry sites, and form open stands with relatively light fuels (Shiplett and Neuenschwander 1994).

Grand fir can dominate regeneration in the grand fir, western hemlock, and western redcedar habitat types series (Ferguson and Carlson 1993). Extremely dense regeneration often occurs on harvested sites (Ferguson 1994). Dispersed seed can be destroyed by fires occurring in the fall.

Grand fir germinates best on ash or mineral soil but is vulnerable to damage from insolation on south and west aspects (Fisher 1935; Foiles and others 1990). It establishes well on unburned sites, in small openings, and in shrubfields. It often germinates and becomes established under closed canopies as well. Damping-off fungi and other biotic agents take a heavy toll of seedlings during wet seasons; drought and insolation cause mortality when conditions are dry. Not until their third year are seedlings well established. The first grand fir seedlings on the Sundance Burn in northern Idaho were found 4 years after the fire.

When grand fir is able to dominate a stand from the time of initial establishment, it achieves optimum growth. In full sun, however, grand fir seedlings are often overtopped by seedlings of faster growing species such as western white pine and western larch. Heavy competition delays establishment and restricts growth. Decay, often caused by Indian paint fungus, is more prevalent in slow-growing, suppressed stands than in faster growing stands (Aho 1977). Decay is especially common in trees more than 60 years old (Beckman and others 1994).

Fire Group Two describes the role of fire in dry grand fir habitat types. In presettlement times, fire maintained many of these sites as open forests dominated by ponderosa pine, Douglas-fir, and western larch. Fire Groups Seven through Nine describe the role of fire in more moist habitats, where grand fir is either seral or climax.

Lodgepole Pine (*Pinus contorta*)

Lodgepole pine is common as a seral species in northern Idaho; it occurs occasionally as a climax species as well (Cooper and others 1991). On many sites, fire has been essential to lodgepole pine dominance. Mature lodgepole pine trees are somewhat resistant to fire even though their usually thin bark makes them susceptible to cambium damage (table 5). Lodgepole pines self-prune lower branches, but shade-tolerant species growing underneath can provide fuel ladders into the crown, enhancing the potential for stand-replacing fire.

Lodgepole pine is unique among the trees of the Northern Rocky Mountains in possessing cone serotiny, a key attribute for regeneration after fire. Lodgepole pines in Montana produce nonserotinous (open) cones until they are 20 to 30 years old; at that age, trees capable of producing serotinous (closed) cones begin to do so (Lotan 1975). A temperature of at least 113 °F is required to melt the resin that seals closed cones (Lotan and Critchfield 1990); heat from fire is the only way such temperatures occur in standing lodgepole pines. Closed cones often remain on a tree for 30 years or more (Hellum 1983). Seed from 150 year old cones, embedded in wood, has germinated successfully (Mills 1915). Large quantities of seed from closed cones are usually available to regenerate lodgepole pine stands after severe fire; a stand of lodgepole pines producing serotinous cones can store 0.2 to 3.2 million seeds per acre (Lotan 1975). However, very severe fires occasionally destroy much of the seed supply, causing sparse regeneration (Romme 1993).

Most mature lodgepole pine stands contain trees that have both closed and open cones. The ratio of closed to open cones is highly variable. In the forests of Fire Group Eight, approximately 39 percent of lodgepole pines produce closed cones, but the proportion within individual stands varies from 0 to nearly 100 percent (Lotan 1975). The proportion of trees producing closed cones may be related to fire regime (Perry and Lotan 1979). Severe burns within 30 to 50 years of each other may favor an increase in cone serotiny. If severe fire is excluded for a long time, lodgepole pine stands may become dominated by open-coned trees as regeneration from open cones replaces the original trees (Muir 1984).

Other characteristics that contribute to lodgepole pine's success in dominating severe burns include high seed viability, high seedling survival, rapid seedling growth on open sites and mineral soils, and early seed production. Cones bearing viable seed are produced by lodgepole pines as young as 5 years in open stands and by trees 15 to 20 years old in dense stands. Since most early seed is in open cones, this seed source fills voids left by initial postfire regeneration from serotinous cones.

Despite heavy use of lodgepole pine seedlings by wildlife species (Lindsey 1975), lodgepole pine regeneration often forms dense stands. Such stands are susceptible to stagnation, snow breakage, and windthrow. As they age, they are also vulnerable to attack by mountain pine beetle (*Dendroctonus ponderosae*). These factors can cause extreme buildup of dead woody fuel on the forest floor, which enhances the potential for another severe fire.

Mature lodgepole pines can survive low-severity fire. In a study that included samples from northern Idaho, Peterson and Arbaugh (1986) found that crown scorch and basal scorch were the best predictors of mortality. Trees that survive low-severity fires do not usually show increased growth rates. If basal scorch occurs, or if 30 percent or more of the crown is scorched, growth is likely to decrease (Peterson and others 1991). Fire-injured trees are susceptible to decay and infestation by insects, especially pine engraver (*Ips pini*). However, they are not especially attractive to mountain pine beetle (Amman and Ryan 1991) until decay has weakened the trees (Gara and others 1985). Lodgepole pine can regenerate in fire-thinned stands from open cones, if the burn exposed some mineral soil; if the duff was moist and did not burn well, regeneration may be slow.

Lodgepole pine dominates Fire Group Three stands. Nearly pure successional stands of lodgepole pine can occur in the habitat types of Fire Groups Two, Four, Five, Seven, and Eight. Characteristics common to these communities are described in "Seral Lodgepole Pine," p. 43.

Mountain Hemlock (*Tsuga mertensiana*)

Mountain hemlock has low resistance to fire damage (table 5). The moderately thick bark of mature trees affords some protection, but highly flammable foliage and a tendency to grow in dense stands make it vulnerable. Its tendency to maintain low-hanging branches exacerbates this susceptibility to fire (Means 1990). Trees that survive fire often suffer subsequent mortality from fungus-infected fire wounds.

Typical mountain hemlock sites are moist, with average annual precipitation over 50 inches and annual snowfall averaging 320 to 500 inches. Fires are usually infrequent. When conditions are dry enough for fires to spread, however, fire behavior is often severe.

Successional patterns vary in the mountain hemlock series. Spruce, subalpine fir, and lodgepole pine are the most important seral species. Burns in mountain hemlock stands along the Idaho-Montana divide north of Lolo Pass have regenerated with lodgepole pine dominant (Cooper and others 1991). Western larch, western white pine, Douglas-fir, and whitebark pine also occur in seral stands of the mountain hemlock series, sometimes becoming dominant after lodgepole pine declines. Occasionally, mountain hemlock establishes after disturbance in nearly pure stands or with subalpine fir.

Mountain hemlock establishment is uncertain and growth is slow. Adequate moisture is essential. Growth is best under partial shade, and regeneration is good under a closed canopy. Seedlings and saplings survive prolonged suppression and respond well to release.

Fire effects on mountain hemlock communities are described in Fire Groups Four, Five, and Six.

Pacific Yew (*Taxus brevifolia*)

Pacific yew can grow either in shrub form or as a short, many-branched, upright tree. In either form, yew is very sensitive to heat damage (Bolsinger and Jaramillo 1990). Although yew resprouts profusely after mechanical disturbance and tolerates considerable bole damage without decreases in growth (Minore and Weatherly 1994), it is killed by fires of any severity unless located on a protected, unburned microsite (Crawford 1983). Pacific yew occurs in forests characterized by long fire return intervals and is absent from areas with high fire frequency.

Pacific yew regenerates vegetatively and from seeds dispersed by birds; some soil-stored seed may be viable (Bolsinger and Jaramillo 1990; Hofman 1917). Since Pacific yew requires cool, moist, shady conditions for establishment, it does not regenerate on severely burned sites until an overstory canopy has developed.

After establishment, Pacific yew continues to increase slowly in cover for at least 500 years. It is considered a climax species that can replace itself on some sites to the exclusion of tall conifers, which regenerate only in canopy gaps (Crawford and Johnson 1985). Following Cooper and others (1991), this report treats yew as a shrub species, its most common structural form in northern Idaho.

Fire effects in forests containing Pacific yew are described in Fire Groups Seven through Nine.

Ponderosa Pine (*Pinus ponderosa*)

Ponderosa pine has many fire-resistant characteristics (table 5). Some saplings can withstand fire when they are as young as 6 years old because of open foliage and relatively deep roots. Saplings 2 inches d.b.h. begin to develop insulative bark. Mature trees have very thick bark, meristems shielded by enclosing needles, and thick bud scales that enable them to withstand fires of low and moderate severity. New cones in tall trees can survive severe fires and initiate regeneration on burned sites.

For ponderosa pine, the likelihood of surviving fire depends mainly on the extent of crown scorch (Oliver and Ryker 1990). Trees burned in spring and summer may be more vulnerable than those burned in autumn (Harrington 1993). Trees with resin deposits around old fire scars are more vulnerable than unscarred trees. The fine roots of ponderosa pine may be more susceptible to spring than fall fires (Grier 1989) and can be damaged by fires burning in deep surface fuels or deep duff. In general, ponderosa pine can be underburned when regeneration reaches 10 to 12 feet in height (Wright 1978). Regeneration reaches breast

height in 8 to 9 years after establishment in PSME/PHMA stands of central Idaho (Steele and Geier-Hayes 1989).

Postburn growth rates in ponderosa pines that survive fire are variable and may be related to crown scorch (Weaver 1968; Wooldridge and Weaver 1965; Wyant and others 1983).

Propagation of fire into the crowns of open-grown ponderosa pines of pole size or larger was unusual under presettlement fire regimes because fire usually removed lower branches, and because trees developed open crowns and thick bark. Trees severely damaged or killed by fire often develop extensive stem decay, which makes them attractive habitat for cavity-nesting birds (Hall 1980; McClelland and Frissell 1975).

Ponderosa pine's fire resistance is enhanced when it grows in open, park-like stands with light fuels, conditions common on dry sites. On moist sites, Douglas-fir and grand fir regeneration often form a flammable layer under the ponderosa pine canopy. These ladder fuels can carry surface fires into the overstory. Consequently, crown fires tend to be more frequent in moist than dry ponderosa pine stands. Dense stands of young ponderosa pine and mature stands with dense regeneration are more susceptible to damage from low-severity fires than open stands because of slow diameter growth and slow development of insulative bark. They may also be susceptible to windthrow after thinning by fire (Simmerman and others 1991).

Ponderosa pine regenerates best on a burned seedbed, although regeneration is often poor after severe fire on dry sites. Postfire conditions minimize competition for moisture for a few years (Fisher 1935; Oliver and Ryker 1990), and may enhance cone growth (Johnsen 1981). Successful establishment, however, requires a seed crop followed by at least one moist growing season. Seed dispersal declines rapidly with distance from the parent tree. A dispersal study in Oregon found that the rate of seedfall 120 feet from the edge of a cleared area was only 22 percent of the rate at the edge of the clearing (Barrett 1979). On some sites, rodent seed caches are an important source of ponderosa pine regeneration (Steele and Geier-Hayes 1994). Seedlings thrive in full sunlight but are vulnerable to drought, temperature extremes, predation, browsing, and disease.

Fire effects in forests where ponderosa pine dominates are discussed in Fire Groups One and Two. Ponderosa pine is an occasional component of stands in Fire Groups Seven and Eight (THPL series).

Subalpine Fir (*Abies lasiocarpa*)

Subalpine fir is the least fire-resistant overstory conifer in northern Idaho because of its thin bark, resin blisters, shallow roots, low and dense branching habit with heavy lichen growth, and stand density (table 5). As a result, fire most often acts as a stand-replacement agent when it burns through subalpine fir forests. Even low-severity fires usually kill the cambium or spread into low branches and from there up into the crown.

Subalpine fir's rate of establishment after fire depends on the availability of seed. Because seeds do not disperse far from the parent tree, regeneration is sparse near the center of large burns but very dense near the edge and within small burns. If initial establishment is sparse, full stocking is delayed until postfire regeneration grows large enough to disperse seed. Subalpine fir can begin producing cones when only 20 years old, but often significant quantities of seed are not produced until age 40 or 50. Maximum seed production is by dominant trees 150 to 200 years old.

Subalpine fir has the ability to germinate and survive on a wide range of seedbeds. Because it germinates well on mineral soil as well as humus (Alexander and others 1990), it can occur in nearly pure stands. More often, it becomes established along with shade-intolerant seral species and grows more slowly than most competitors. Even Engelmann spruce grows faster than subalpine fir when light intensity exceeds 50 percent of full sunlight. Subalpine fir germinates and grows better than most associated species under shade, although competition can suppress growth rates; in an environment with dense lodgepole pine reproduction in Colorado, subalpine fir seedlings grew only 3 feet in 100 years (Peet 1981).

Fire's role in forests dominated by subalpine fir is described in Fire Groups Four through Six.

Western Hemlock (*Tsuga heterophylla*)

Western hemlock is susceptible to fire because of its moderately thin bark, shallow roots, flammable foliage, and low branching habit (Dewberry 1990) (table 5). Western hemlock often grows in dense stands and has lichen-draped branches; these characteristics increase its susceptibility to fire damage. Although hemlocks develop thicker bark with age, they remain vulnerable to fire because their roots remain shallow and heavy fuel loads accumulate, increasing the potential for severe fire.

The seed of western hemlock is light and winged, and can disseminate 2,000 feet or more on open, windy sites. Hemlock germinates well on most natural seedbeds (Packee 1990). Regeneration is generally enhanced by duff removal and reduction of shrub cover. Seedlings are sensitive to drought, wind, and extremes of heat and cold, so partial shade may be needed for successful establishment. Western hemlock grows quickly in full overhead light and more slowly in shade (Packee 1990).

Fire effects in low-elevation and montane western hemlock communities are described in Fire Groups Eight and Nine. Fire Group Five describes fire effects on subalpine sites where western hemlock is the climax species (TSHE/MEFE habitat type).

Western Larch (*Larix occidentalis*)

Western larch is the most fire-resistant conifer in northern Idaho (table 5). Although western larch seedlings and saplings are readily killed by fire, mature trees can survive most fires unless the bole is girdled by long-smoldering surface fire or the buds are killed by torching and crowning. A severe fire in the Idaho portion of the Bitterroot National Forest killed nearly all grand fir, Douglas-fir, and western redcedar but failed to kill most western larch larger than 8 inches d.b.h. (Humphrey and Weaver 1915). Mature western larch possess bark 3 to 6 inches thick near the ground, usually develop deep roots, and self-prune lower branches. Western larch foliage has relatively low flammability and is replaced annually. Western larch is more tolerant of fire-caused defoliation than other conifers in northern Idaho, which normally replace their needles at intervals of 2 or more years. After being scorched by fire, live buds of western larch can drop their dead foliage and initiate new leaves.

Western larch trees that are scarred by fire are vulnerable to insects and diseases, but trees often survive many centuries with large scars. Some large western larch trees survive even large, severe fires. If abundant seed is produced in the first years after fire, western larch dominates early succession. Western larch may respond to thinning by fire with increased radial growth (Reinhardt and Ryan 1988a).

Western larch establishes rapidly on mineral soil exposed by fire. Western larch only 40 to 50 years old can produce abundant cones, although heavy cone crops are irregular, averaging 1 in every 5 years (Schmidt and Shearer 1990). Western larch's lightweight seeds are often transported 800 feet or more. Seed dispersal usually occurs from late August through mid-October (Schmidt and Lotan 1980), so dispersed seed can be destroyed by early fall fires.

Western larch often establishes and grows well after severe fire. Schmidt and Shearer (1990) found that western larch seedlings and saplings grew one-third faster on burned seedbeds than on unburned mineral soil or duff. A species highly intolerant of shade, western larch develops best in nearly full sunlight. However, seedlings and saplings are sensitive to drought and high temperatures. Since western larch survives and grows better on moist than dry sites, it often dominates north- and east-facing slopes.

Western larch is long lived. Fire-scarred tree stumps in western Montana indicate that some trees were older than 900 years at the time of cutting (Koch 1945). Such longevity helps maintain western larch as a stand component and potential seed source well past the time when it dominates early-successional stands. As western larches with broken tops deteriorate through stem decay, they become preferred habitat for many cavity-nesting birds (McClelland and others 1979). Fire-created snags persist for many decades; in northern Idaho, Zack (1994) observed snags still standing 80 years after fire.

Western larch is strictly a seral species; it is an important component of forest succession in Fire Groups Two, Five, Seven, and Eight.

Western Redcedar (*Thuja plicata*)

Western redcedar has moderate fire resistance (table 5). Its thin bark, shallow root system, low and dense branching habit, and highly flammable foliage make it susceptible to fire damage. The most common causes of fire mortality are root charring and crown scorching. Fire injury to roots can lead to fungal infection, chronic stress, and decreased growth. Despite this susceptibility to fire, individuals often survive fire because of their large size and cedar's characteristic tenacity if any portion of the bole is left alive (Habeck and Mutch 1973). Large, fire-scarred cedars are common in northern Idaho. Young trees rarely survive fire (Shiplett and Neuenschwander 1994).

On upland sites, western redcedar is subject to infrequent fires. Where it grows on moist, sheltered sites, the generally moist duff does not burn readily, so fires are infrequent and patchy. Riparian stringers of cedar may act as firebreaks (Fischer and Bradley 1987); however, under drought conditions, severe fires can burn from neighboring sites through cedar stands. When the deep duff and heavy fuels become dry enough to burn, long-smoldering fires can occur.

Western redcedar is a prolific seed producer, so it regenerates on most burned sites early in succession. Cedar germinates well on burned, mineral soil seedbeds (Minore 1990), although its seed does not disperse well over distances greater than 400 feet (Haig and others 1941). Since cedar regeneration is vulnerable to high soil temperatures and slow to develop extensive roots, survival is best under partial shade. Seedlings and saplings grow slowly and are often overtopped early in succession by faster growing species.

Western redcedar can germinate, grow, and even reach maturity under low light. Vegetative reproduction is common; in fact, most regeneration in moist, old-growth stands is vegetative, from adventitious roots developing on low-hanging branches, live fallen trunks, or even live branches that fall on wet soil (Parker 1986).

Fire effects in western redcedar forests are described in Fire Group Eight, where cedar functions either as a long-lived seral species or the climax species, and in the very moist habitat types that comprise Fire Group Nine.

Western White Pine (*Pinus monticola*)

Mature western white pines have some characteristics useful for surviving fire (medium-thick bark, moderately flammable foliage, self-pruning of lower limbs, and tall stature) (table 5). Several reports from northern Idaho indicate that western white pine can survive low-severity fires after they are about 25 years old (Marshall 1928; Rapraeger 1936). However, the species is not generally considered fire resistant (Bradner and Anderson 1930; Wellner 1976). Mature trees usually succumb to cambium and crown damage from fire. Older trees have lichen-covered branches, making them more vulnerable to fire than other high-crowned species such as western larch and ponderosa pine. Trees that survive fire are susceptible to fungi that enter through fire-caused wounds (Rapraeger 1936). Young western white pines are more vulnerable to fire than mature trees because of thin bark, compact stand structure, and retention of lower limbs.

Western white pine regenerates readily after most fires, establishing well on ash and mineral soil if moisture is sufficient (Fisher 1935; Graham 1990). Prior to widespread harvesting, the species depended on severe fires to create conditions optimum for regeneration (Shiplett and Neuenschwander 1994). Historically, the dominance of western white pine in the nearly even-age overstory of large stands was evidence of colonization after fire.

Western white pine seed can be stored in the duff, but viability is less than 1 percent after 3 years. Most seed falls within 400 feet of the parent tree, although seed is occasionally dispersed half a mile or more (Graham 1990). Seed may also be released from the crowns of fire-killed trees (Haig and others 1941). On moist sites, seedlings thrive in the open. Because they are sensitive to heat and late-season drought, they benefit from shade on dry sites.

Western white pine often regenerates in complex mixtures of seral species. Composition and structure of early-successional forests are determined during the first 30 to 40 years after fire. Western white pine regeneration outgrows Douglas-fir and western larch regeneration by about 40 years of age and can retain this advantage for a century or more (Watt 1960). Mortality and self-pruning caused by low-severity fires determine the subsequent composition and fire resistance of the stand (Covington and others 1994). Western white pine's longevity (400 to 500 years) enables it to remain a stand component for several centuries following major disturbance. It is more resistant to root diseases than its shade-tolerant associates (Harvey and others 1994).

Western white pine is now a minor species in many areas where it once dominated successional forests. In 1933, the western white pine cover type comprised 32 percent of the area of the Priest River Experimental Forest; in 1976, it comprised about 5 percent (Wellner 1976). Western white pine's proportion of the tree regeneration in northern Idaho, eastern Washington, and western Montana was reported as 44 percent in 1941 but had decreased to 5 percent by 1979 (Graham 1990). Western white pine blister rust (*Cronartium ribicola*) infection, mountain pine beetle infestation, selective harvesting, and fire exclusion have been the major causes of this decline (Graham 1990; Wellner 1976). Blister rust readily girdles seedling and sapling western white pines, causing most of its damage in the first two decades of regeneration. Blister rust makes western white pines less able to produce seed to colonize a burn (Shiplett and Neuenschwander 1994). Large-diameter infected trees are often killed by mountain pine beetle (Graham 1990; Kulhavy and others 1984), increasing fuels and thus the potential for severe fire.

The loss of western white pine as the dominant early successional species over large areas in northern Idaho has changed the ecology of entire forest communities. As western white pine populations and reproduction have declined, grand fir has become more important in succession (Ferguson 1994). The susceptibility of grand fir to root pathogens (Haig and others 1941) reduces productivity on sites formerly dominated by western white pine and accelerates succession to climax species.

Management strategies to increase western white pine combine the use of rust-resistant varieties with careful site analysis. Hagle and others (1989) suggested careful attention to control of *Ribes* species and evaluation of the level of blister rust resistance when planning for management of existing western white pine stands and for any site where western white pine may be desired.

Western white pine is strictly a seral species, an important component of forest succession in Fire Groups Seven and Eight, and occasionally in Group Five.

Whitebark Pine (*Pinus albicaulis*)

Whitebark pine is a moderately fire resistant species (table 5) that often pioneers after fire on high-elevation sites. Although whitebark pine is present on relatively few sites in northern Idaho, it is important because of its ability to thrive in locations too severe for other tree species and its importance as a source of wildlife food (Kendall and Arno 1990; Tomback 1989).

White pine blister rust has contributed to a severe decline in northern Idaho's whitebark pine populations in recent decades.

Whitebark pine occurs as a seral species in many subalpine forests and is the potential climax species on dry upper subalpine and timberline sites (Arno 1986). It has relatively thin bark and so is susceptible to injury from moderate to severe fires. However, where whitebark pine grows in exposed habitats with an open stand structure and sparse undergrowth, it survives most fires (Arno 1986). Whitebark pines reach ages exceeding 700 years (Arno and Hoff 1989).

Although whitebark pine seeds are large and wingless, they often regenerate on burns without nearby seed sources. Seedlings occur in clumps originating from seed caches established by Clark's nutcrackers (*Nucifraga columbiana*) (Tomback 1989). Not all seeds within a cache necessarily germinate in the same year, so regeneration is a gradual process (Tomback 1994). Nutcrackers prefer open to closed stands as cache sites (Arno 1994). Whitebark pine seedlings require warm summers for vigorous growth but are not especially dependent on seasonal moisture levels (Hutchins and Lanner 1982).

Near its lower elevational limit, whitebark pine often occurs with lodgepole pine, subalpine fir, Engelmann spruce, and occasionally mountain hemlock. On these sites, it is perpetuated by occasional low-severity fires that kill most of whitebark pine's associates but leave some pines that regenerate the stand (Morgan and Bunting 1989, 1990). Severe fires kill all trees in mixed stands, but whitebark pine can regenerate readily despite great distance from seed sources.

The most common fires within whitebark pine stands are caused by lightning and do not spread far. During extended dry periods of high fire danger, these fires can spread downhill into dense lower elevation forests. More often, severe wildfires starting in lower forests spread through whitebark pine stands to timberline, although the open structure of high-elevation whitebark pine stands can slow fire spread (Arno and Hoff 1990).

Whitebark pine has declined severely in recent years due to the combined effects of mountain pine beetle and white pine blister rust. Mountain pine beetles attack mature stands of whitebark pine, especially when beetle populations are very high in adjacent lodgepole pine forests and when the trees are already weakened by blister rust (Keane and Arno 1993). Whitebark pine mortality in northern Idaho was more than 90 percent in the Selkirk Range by the early 1980's (Kendall and Arno 1990). Mortality from mountain pine beetle and blister rust produces locally heavy fuel loadings, which increase the potential for severe fire.

Mature whitebark pines infected by blister rust live for several years, but they fail to produce seed (Keane and Arno 1993). Regeneration is further limited if high-elevation openings are not available for nutcracker cache sites. Management-ignited fire on Group Six sites increases opportunities for regeneration and selection of rust-resistant genotypes (Arno 1994). It can also increase *Ribes* cover, enhancing blister rust inoculum in regeneration. Where *Ribes* cover is increased, the immediate potential for whitebark pine regeneration is reduced, but the process of selection for blister rust resistance accelerates.

Fire effects in stands dominated by whitebark pine are described in Fire Group Six.

Undergrowth Response to Fire ____

Many of the common shrubs and herbaceous plants that grow in northern Idaho forests can renew themselves from plant parts that survive fire. Other plants are quite susceptible to fire-kill and reestablish or colonize from off-site seed sources near the burned area.

Stickney (1982) described the process of postfire plant succession following fire in Northern Rocky Mountain forests:

> ...the severity of the disturbance treatment directly affects the representation of the survivor component in the postfire vegetation. Since survivors derive from plants already established at the time of disturbance, it is possible, by pretreatment inventory, to determine the potential composition for the survivor component. For this reason it also follows that forest stands with little undergrowth vegetation could be expected to have a sparse or limited survivor component following disturbance. In addition, if the [survivor] component is composed mostly of shade-tolerant climax-like species the rate of survivor recovery can be expected to be slow. Nearly all of our native forest shrub species are capable of surviving burning, and they can therefore be expected to function as survivors. A majority of the predisturbance forest herb species also demonstrated the ability to survive fire, particularly those species with underground stems (rhizome) or rootcrowns (caudex). As a generalization, the more severe the fire treatment to vegetation, the less the survivor component. In the drier, more open forest types this usually results in a reduction of amount, but not major changes in composition. However, in the moister forest types, where the undergrowth is made up of more mesic shade-tolerant species, marked changes in postfire composition can occur as increasing severity reduces survivor representation.
>
> The severity of disturbance treatment (particularly fire) influences the potential for colonizer presence in two ways: (1) the degree of severity creates the character of the ground surface on which colonizer seedlings germinate, and (2) it activates onsite stored seed. Generalizing, the more severe the disturbance treatment the more favorable the site becomes for colonizers. As the extent of exposed mineral soil increases, the ground surface becomes more favorable as a site for germination and establishment of colonizer plants. Increases in treatment severity also favor germination of ground-stored seeds by increasing their exposure to light or heat.
>
> Predicting the occurrence of colonizers in postdisturbance vegetation is much less certain than predicting for survivors, but knowledge of the previous succession history can provide

the potential composition of residual colonizers. Locally this information is often available from an adjacent or nearby clearcut. Least predictable is the offsite colonizer component, for its occurrence is dependent on the timing of the disturbance to the availability and dispersal of offsite airborne seed. Even in this case reference to local clearcuts can provide some idea of the composition for the most common offsite colonizer species likely to occur.

Table 6 briefly summarizes responses to fire for many plant species that occur in northern Idaho forests. Species are grouped according to growth form, then listed alphabetically according to scientific name. Plant responses are generalized, and the list is not comprehensive. Up-to-date information concerning the effects of fire on many of these species, and others, is available through the Fire Effects Information System (Fischer and others 1996). Plant response to fire depends on many factors, including soil and duff moisture, plant vigor, phenological state at the time of burning, and fire severity. Response also depends on stand history. As organic material accumulates between fires, seedlings and new rhizomes of some species become established in the organic horizons. There, they are more vulnerable to fire than plants established in mineral soil, especially if heavy fuels have accumulated and increased potential fire severity (Bradley 1984).

Fire Effects on Animals

Idaho has a diverse fauna consisting of more than 500 vertebrates alone (Groves and Unsworth 1993) (fig. 3). Fire changes the structure and species composition of forest stands, and alters the size and distribution of various structures across the landscape; these effects have powerful, long-lasting influences on wildlife populations and communities. Detailed summaries of fire effects on many animal species in northern Idaho are available in the Fire Effects Information System (Fischer and others 1996).

Immediate, Direct Effects

Fires may directly reduce populations of invertebrates that reside in or deposit eggs in the surface vegetation or the forest floor. Species that reside in aerial vegetation or underground are less susceptible to fire. Mature individuals of most species fly away or move quickly into the soil; some are protected by insulative properties of the trees that they inhabit. Some flying insects are attracted by heat, smoke, or burned vegetation (Lyon and others 1978).

Among the vertebrates, fire-caused injury and death are usually limited to a few individuals. Most large mammals avoid burning areas (although they often remain close) and are able to escape from fire. Many birds escape by flying, though some may be attracted to fire. Small vertebrates usually find shelter underground (Lyon and others 1978). Direct effects of fire can threaten vertebrate populations, if they are already small or if the species is very limited in range and mobility.

Indirect Effects and Animal Responses

The postfire environment presents animals with a modified habitat structure and microclimate. The extent of change depends on the size, severity, and spatial continuity of the burn. Changes after low- and mixed-severity fires are less drastic than those after severe fire, which alters both the forest structure and the microclimate dramatically, increasing light and temperature at the ground level, increasing surface wind velocities, and modifying snow cover (Lyon and others 1978). A complete assessment of fire effects on animals would evaluate effects of a variety of fire regimes on species at all trophic levels, and would consider habitat at the microsite, stand, and landscape levels throughout succession. This report briefly describes indirect effects of fire for groups of animal species occurring in northern Idaho. We discuss vertebrate species here, including information on invertebrates as prey. Other information on invertebrates relates to specific forest communities; where appropriate, it is presented within fire group descriptions.

Large Mammals—The forests of northern Idaho support all species of cervids occurring in North America: white-tailed deer (*Odocoileus virginianus*), mule deer (*Odocoileus hemionus*), elk (*Cervus elaphus*), caribou (*Rangifer tarandus*), and moose (*Alces alces*). The habitat requirements of these species span the range of forest structures that occur during stand development. Mule deer use open shrub fields, often on steep south slopes, in winter; they use higher elevation sites in summer (Keay and Peek 1980). Elk depend on herb cover in early spring and seral shrubs in summer and winter; they use dense pole-sized forest heavily in fall (Irwin and Peek 1983). White-tailed deer exploit a variety of successional stages and forest structures; their winter requirements may be related to snow depth. In the Selway-Bitterroot Wilderness, white-tailed deer use open habitats with bunchgrass cover in mid-winter (Keay and Peek 1980). In the Priest River drainage (Kaniksu National Forest), white-tails stay in old-growth forests when snow depth reaches 1 to 2 feet. They use open-canopied habitats for the first snow-free forage in spring (Yeo and Peek 1994). Habitat requirements for moose also vary. In the southern Clearwater National Forest and Nez Perce National Forest, moose require old-growth forests containing Pacific yew or subalpine fir browse during winter. Further north, they rely heavily on seral stands of tall shrubs, especially where shrubfields are interspersed with closed-canopy forest. Caribou

Table 6—Summary of postfire survival strategy and fire response information of some plant species occurring in forests of northern Idaho. Information here is taken from species summaries in the Fire Effects Information System (FEIS) (Fischer and others 1996) and also from Armour and others (1984), Arno and others (1985), Ash and Lasko (1990), Bradley and others (1992a,b), Britton and others (1983), Coates and Haeussler (1986), Comeau and others (1989), Crane and others (1983), Daubenmire and Daubenmire (1968), Fischer and Bradley (1987), Freedman (1983), Fulbright (1987), Hawkes and others (1990), Keown (1984), Kramer (1984), Lotan and others (1981), Lyon (1966, 1971), Lyon and Stickney (1976), McLean (1969), Miller (1977), Morgan and Neuenschwander (1988a,b), Mueggler (1965), Noste (1985), Rowe (1983), Shiplett and Neuenschwander (1994), Steele and Geier-Hayes (1989, 1993), Stickney (1981), Viereck and Dyrness (1979), Vogl and Ryder (1969), Volland and Dell (1981), Woodard (1977), Wright (1972, 1978), Zager (1980), Zamora (1975), and Zimmerman (1979).

Species	Fire survival strategy	Comments on fire response
Shrubs and Other Woody Species		
Acer glabrum[a,b,c] Rocky Mountain maple	Sprouts from surviving crown or caudex. Colonizes from wind-dispersed seed.	Usually increases following fire. Survival and response may be reduced by severe surface fire.
Alnus incana Thinleaf alder	Sprouts from surviving root crown or caudex; off-site seed dispersal by wind and water.	Increased density because multiple stems arise from each burned plant. Late summer burns are immediately colonized by fall seed crop.
Alnus sinuata[a,b,c] Sitka alder	Sprouts from surviving root crown.	Usually increases following fire. Early seed production (after 5 years) aids increase.
Amelanchier alnifolia[a,b,c] Serviceberry	Sprouts from surviving root crown. Colonizes from seed.	Usually survives even severe fires especially if soil is moist at time of fire. Coverage may decrease and frequency increase following fire.
Arctostaphylos uva-ursi[a,b,c] Bearberry	May sprout from root crown or caudex; regeneration from stolons more common. May have somewhat fire resistant seeds stored in soil.	Very susceptible to fire-kill, but resprouts vigorously if any plant parts remain alive after burning. May invade burned areas from unburned patches.
Mahonia repens[a,b,c] Creeping Oregon grape	Sprouts from surviving rhizomes that grow 0.5 to 2 inches below soil surface.	Moderately resistant to fire-kill. Usually survives all but severe fires that remove duff and cause extended heating of upper soil.
Ceanothus sanguineus[a,b,c] Redstem ceanothus	Sprouts from root crown or stem base; seeds require heat scarification.	Resistant to fire. Usually increases rapidly after fire.
Ceanothus velutinus[a,b,c] Shinyleaf ceanothus	Soil-stored seed requires heat for germination. Sprouts from root crowns and roots following low-severity fire.	Increases after fire, except after repeated low-severity burns. Increases dramatically after severe burns. Can dominate site within 2 to 11 years.
Cornus canadensis Bunchberry dogwood	Sprouts from surviving rhizomes that grow 2 to 5 inches below soil surface.	Moderately resistant to fire-kill. Survives all but severe fires that remove duff and cause extended heating of upper soil.
Cornus sericea Red-osier dogwood (formerly *Cornus stolonifera*)	Sprouts from surviving rhizomes, stolons (runners), and base of stem, or regenerates from soil-stored seed.	Survives all but severe fires that remove duff and cause extended heating of upper soil. Generally increases following fire.
Crataegus douglasii Black hawthorn	Sprouts from roots or root crown.	Moderately susceptible to fire. May require years of growth for full reestablishment.

(con.)

Table 6—Con.

Species	Fire survival strategy	Comments on fire response
Holodiscus discolor[a,b,c] Ocean-spray	Regenerates from soil-stored seed or sprouts from surviving root crown.	Moderately resistant to fire-kill. Is often enhanced by fire.
Linnaea borealis[a,b,c] Twinflower	Sprouts from surviving root crown located just below soil surface. Fibrous roots and runners at soil surface.	Susceptible to fire-kill. May survive fires in which duff is not consumed. Can invade burned area from unburned patches.
Lonicera utahensis[a,b,c] Utah honeysuckle	Sprouts from surviving root crown.	May decrease in cover and frequency following fire.
Menziesia ferruginea[a,b,c] Fool's huckleberry	Sprouts from surviving root crown.	Susceptible to fire-kill. Moderate to severe fires reduce density and retard recovery.
Oplopanax horridum Devil's club	May sprout from root crown.	Susceptible to fire-kill.
Pachistima myrsinites[a,b,c] Pachistima	Sprouts from surviving root crown and from buds along taproot.	Moderately resistant to fire-kill. Usually survives low to moderate severity fires that do not consume the duff and heat soil excessively. Usually increases.
Philadelphus lewisii Syringa	Sprouts from root crown. Colonizes from seed.	Fire resistant; a vigorous resprouter.
Physocarpus malvaceus[a,b,c] Ninebark	Sprouts from surviving root crown or horizontal rhizomes.	Resprouts after fire, but recovery may be slow if roots are damaged by severe fire.
Prunus emarginata[c] Bitter cherry	Sprouts from surviving root crown. Germinates from soil-stored seed.	Top-killed by severe fires. Usually increases after fire.
Prunus virginiana[a,b,c] Common chokecherry	Sprouts from surviving root crown, occasionally from rhizomes; also regenerates from on-site seed.	Usually increases after fire, although cover may decrease for 1 year.
Rhododendron albiflorum White rhododendron	May resprout from root crown.	Susceptible to fires of moderate to high severity. Slow to recover.
Ribes cereum[a,b,c] Wax currant	Germinates from heat-scarified on-site seed.	Seldom survives fire. Fire favors establishment from soil-stored seed.
Ribes lacustre[a,b,c] Prickly currant	Germinates from heat-scarified on-site seed. Shallow roots are killed by most fires.	Soil-stored seed probably survives most fires. Mature plants may occasionally survive very low-severity fire.
Ribes viscosissimum[a,b,c] Sticky currant	Soil-stored seed may germinate after scarification by fire.	Susceptible to fire-kill. Can regenerate profusely from seed. Relatively shade intolerant. May contribute substantially to postfire revegetation.
Rosa gymnocarpa[a,b,c] Baldhip rose	Sprouts from surviving root crowns and rhizomes.	Resistant to fires of low to moderate severity.
Rosa woodsii[a,b,c] Pearhip rose	Sprouts from surviving root crowns.	Some ecotypes can spread by root sprouting.
Rubus parviflorus[a,b,c] Western thimbleberry	Sprouts from surviving rhizomes and root crown; seedlings from soil-stored and possibly bird-dispersed seed.	Sometimes enhanced by fire. Can spread vigorously from rhizomes and recover rapidly after fire.

(con.)

Table 6—Con.

Species	Fire survival strategy	Comments on fire response
Salix scouleriana[a,b,c] Scouler willow	Multiple sprouts from root crown. Colonizes from wind-dispersed seed.	Resprouts vigorously even after severe fire. Seeds germinate rapidly on moist burned sites.
Sambucus racemosa[b,c] Elderberry	Sprouts from root crown. Germination of fire-activated on-site seed in soil.	Seed germination may be extensive; response may decline with repeated burning.
Shepherdia canadensis[a,b,c] Buffaloberry	Sprouts from surviving root crown and from buds along taproot.	Moderately resistant to fire-kill. Usually survives cool to moderately severe fires that fail to consume duff. Usually increases.
Sorbus scopulina[a,b,c] Mountain-ash	Sprouts from root crown.	May resprout after fire.
Spiraea betulifolia[a,b,c] Spiraea	Sprouts from surviving root crown and from rhizomes that grow 2 to 5 inches below soil surface.	Resistant to fire-kill. Usually survives fire and increases in cover after fire.
Symphoricarpos albus[a,b,c] Common snowberry	Sprouts vigorously from underground rhizomes and from root crown or caudex.	Survives most fires but may be susceptible to frequent burning. May produce fruit in first postfire year.
Taxus brevifolia Pacific yew	Colonizes from off-site seed, usually after cover is established.	See "Relationships of Major Tree Species to Fire."
Vaccinium caespitosum[c] Dwarf huckleberry	Sprouts from shallow rhizomes; off-site animal-transported seed.	Sprouts may quickly reoccupy a site after low- to moderate-severity fire.
Vaccinium globulare[a,b,c,d] Blue huckleberry	Sprouts from dense network of shallow and deep rhizomes.	Usually survives low- and moderate-severity fires. Recovery after severe fire may require 15 to 20 years.
Vaccinium myrtillus[b,c] Dwarf bilberry	Sprouts from root crown or from extended network of underground rhizomes.	May be virtually eliminated from a site by severe fire.
Vaccinium scoparium[a,b,c] Grouse whortleberry	Sprouts from surviving rhizomes, which grow in duff layer or at surface of soil.	Moderately resistant to fire-kill. Usually survives fires that do not consume the lower layer of duff.
Grassy Species		
Calamagrostis canadensis Bluejoint reedgrass	Invader, wind-disseminated seed; also an enduring sprouter.	Increases on moist to wet postfire sites.
Calamagrostis rubescens Pinegrass	Sprouts from surviving rhizomes which grow within the top 2 inches of soil. May colonize from wind-dispersed seed.	Moderately resistant to fire-kill. Usually survives fires that do not completely consume duff. Often invades burns.
Carex geyeri[a] Elk sedge	Sprouts from surviving rhizomes. Colonizes from soil-stored seed.	May increase following fire. Often invades following fire.
Carex rossii[a] Ross sedge	Seed stored in duff or soil germinates when heat treated. Sprouts from surviving rhizomes.	Usually increases after fires severe enough to heat soil but not completely consume duff.
Festuca idahoensis Idaho fescue	Seed germination and survival of residual plant.	Susceptible to fire-kill. Can be seriously harmed by severe fires. Only slightly damaged during spring or fall fires with high soil moisture.

(con.)

Table 6—Con.

Species	Fire survival strategy	Comments on fire response
Luzula hitchcockii Smooth woodrush	Sprouts from surviving rhizomes.	Often increases slightly following fire.
Pseudoroegneria spicata Bluebunch wheatgrass (formerly *Agropyron spicatum*)	Seed germination and some sprouts from surviving growing points.	Usually not seriously damaged by fire. Response depends on severity of fire and physiological state of plant. Damage will be greatest following dry year.
Forbs		
Achillea millefolium Common yarrow	Sprouts from extensive rhizomes.	Survives most fires, can increase cover rapidly.
Actaea rubra Baneberry	Sprouts from thick underground caudex; off-site animal-transported seed.	Vigorous growing sprouts may occur the first year after fire.
Adenocaulon bicolor Trail-plant	Sprouts from rhizomes near mineral soil surface.	Moderately susceptible to fire-kill. May survive moderately severe fires unless they consume lower duff.
Aralia nudicaulis Wild sarsaparilla	Sprouts from surviving rhizomes.	Generally resistant to fire-kill.
Arnica cordifolia Heartleaf arnica	Sprouts from surviving rhizomes, which creep laterally from 0.4 to 0.8 inch below soil surface. Colonizes from wind-dispersed seed.	Susceptible to fire-kill. Shoots produce small crowns within the duff. These are easily killed by all but low-severity fires that occur when duff is moist. May rapidly invade burned area via wind-borne seed.
Arnica latifolia Mountain arnica	Sprouts from laterally creeping rhizomes.	Susceptible to fire-kill. Survives some fires, and may exhibit rapid initial regrowth accompanied by heavy flowering and dense seedling establishment.
Asarum caudatum Wild ginger	Colonizes from off-site seed.	Very fire-sensitive. Even low-severity fires kill most plants.
Aster conspicuus Showy aster	Sprouts from surviving rhizomes that mostly grow from 0.5 to 2 inches below soil surface.	Moderately resistant to fire-kill. Usually survives fires that do not result in excessive soil heating. May increase rapidly after fire.
Athyrium filix-femina Ladyfern	Resprouts from surviving rhizomes.	Fire-sensitive; decreases in cover on drier sites, but may resprout on very moist sites.
Balsamorhiza sagittata Arrowleaf balsamroot	Regrowth from surviving thick caudex.	Will survive even the most severe fire. Increases in frequency and density after fire.
Chimaphila umbellata Prince's pine	Rhizomes in duff near mineral soil surface.	Susceptible to fire-kill. May survive fire if duff not heated appreciably.
Clintonia uniflora Queencup beadlily	Sprouts from surviving rhizomes.	Usually decreases following fire. Postfire environment evidently not conducive to rapid recovery.
Coptis occidentalis Western goldthread	Resprouts from slender rhizomes.	Fire sensitive; generally reduced following fire.

(con.)

Table 6—Con.

Species	Fire survival strategy	Comments on fire response
Disporum hookeri Wartberry fairybell	Resprouts from rhizomes.	Initially decreased by fire but recovers to preburn levels relatively rapidly.
Epilobium angustifolium Fireweed	Establishes from wind-blown seed and sprouts from rhizomes.	Needs mineral soil to establish, can persist vegetatively and flower the first summer following fire. Usually increases substantially after severe fire.
Erythronium grandiflorum Dogtooth-violet	Resprouts from corm 5 to 7 inches below soil surface.	Resistant to fire-kill. Fire destroys current year's seed, so frequent fires reduce species.
Fragaria virginiana Strawberry	Sprouts from surviving stolons (runners) at or just below soil surface.	Susceptible to fire-kill. Often survives fires that do not consume duff.
Galium triflorum Sweetscented bedstraw	Sprouts from surviving rhizomes.	Susceptible to fire-kill. Usually decreases sharply following severe fire. Can increase following spring and fall fires.
Iliamna rivularis Streambank globemallow	Colonizes from soil-stored seed. Seeds require heat to germinate.	Responds vigorously to severe burning. A short-lived species.
Lupinus species Lupine	Resprouts from root crowns and colonizes from soil-stored seed.	Coverage little affected by fire.
Osmorhiza chilensis Mountain sweet-cicely	Short shallow roots; barbed, animal-dispersed seeds.	Moderately fire-resistant; temporary increase after fire.
Polystichum munitum Western swordfern	Sprouts from woody rhizome. Colonizes from off-site seed.	Burning has variable results depending on fire severity and soil moisture. Cover may be reduced or lacking for several years after fire.
Pteridium aquilinum Bracken fern	Well adapted; profusely sprouts from surviving rhizomes; off-site wind carried spores.	New sprouts are vigorous and produce abundant spores in fire created openings. Sprouting is slow following summer fire.
Pyrola secunda One-sided wintergreen	Sprouts from surviving rhizomes, which grow mostly in the duff or at soil surface.	Susceptible to fire-kill. Coverage frequently reduced following fire. May survive cool fires when duff moisture is high.
Senecio triangularis	May resprout after fire.	Generally remains unchanged or increases after fire. Protected by usually moist site conditions.
Smilacina racemosa False Solomon's seal	Sprouts from surviving stout creeping rhizomes.	Moderately resistant to fire-kill. May be killed by severe fires that remove duff and heat soil excessively. Usually maintains prefire frequency.
Smilacina stellata Starry Solomon-seal	Sprouts from surviving creeping rhizomes.	Moderately resistant to fire-kill. May be killed by fires that remove duff and heat upper soil. Frequency often reduced following fire.

(con.)

Table 6—Con.

Species	Fire survival strategy	Comments on fire response
Streptopus amplexifolius Twisted-stalk	Extensively rhizomatous.	Decreased by fire.
Thalictrum occidentale Western meadowrue	Sprouts from surviving rhizomes.	Susceptible to fire-kill. Frequency usually reduced after fire. May survive low-severity fires that do not consume duff.
Trautvetteria caroliniensis False bugbane	Widely spreading rhizomes.	Slight decrease after fire.
Valeriana sitchensis Sitka valerian	Colonizes from off-site seed.	Fire-sensitive. Severely reduced by fires that kill rhizomes and roots.
Xerophyllum tenax[a,b,c] Beargrass	Sprouts from surviving stout shallow rhizome.	Susceptible to fire-kill. Survives low-severity fires that do not consume lower duff. Resprouts flower vigorously after fire until new canopy develops.

[a]Included in the SHRUBS extension of the Prognosis Model (Moeur 1985).
[b]Equations for predicting frequency of occurrence available in Scharosch (1984).
[c]Equations for predicting height and cover in different seral stages, with different management scenarios, available in Laursen (1984).
[d]Often intergrades with *Vaccinium membranaceum* in northern Idaho (Cooper and others 1991).

use spruce-fir forests containing arboreal lichens (*Alectoria* species) during the winter (Edwards and others 1960). In spring, caribou range into openings where succulent green forage occurs. Fire-caused expansion of openings and shrubfields may attract predators to caribou habitat, increasing the risk of predation to this sensitive species (Yeo and Peek 1994).

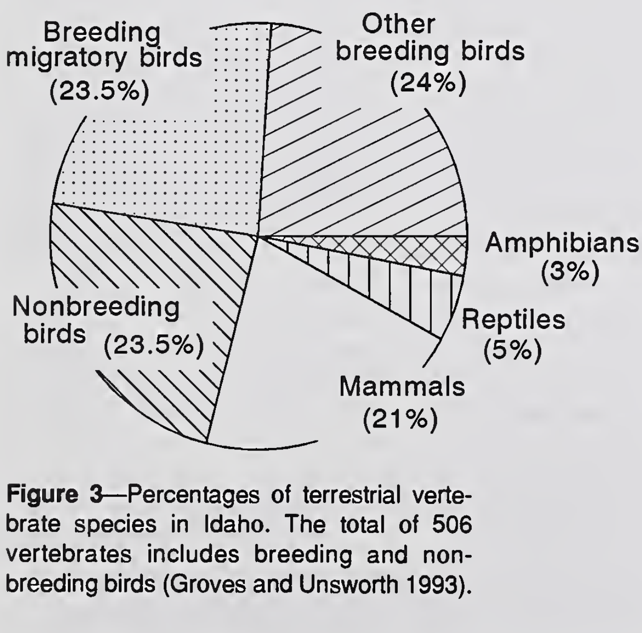

Figure 3—Percentages of terrestrial vertebrate species in Idaho. The total of 506 vertebrates includes breeding and nonbreeding birds (Groves and Unsworth 1993).

Optimum habitat for omnivores and carnivores is, of course, related to availability of prey and carrion. Where prey becomes more plentiful or easier to hunt after fire, predators benefit (Kramp and others 1983). Many species use burns seasonally in response to high food availability. The American marten (*Martes americana*), for instance, a resident of mature forest during winter, often uses fire-caused openings in summer and fall to obtain small mammals, insects, and fruits (Koehler and Hornocker 1977). In the Selkirk Mountains (Kaniksu National Forest) and the Selway-Bitterroot Wilderness, grizzly and black bear (*Ursus arctos* and *U. americanus*) historically used burns in the forb and shrub stages for summer and fall food (Almack 1986; Davis and others 1986). Huckleberries are heavily used by bears; in western Montana, they are prevalent in burns 25 to 70 years old, especially on mesic sites (Martin 1979; Zager 1980). Much of the fall food supply of both grizzly and black bears was historically obtained from caches of whitebark pine cones made by red squirrels (*Tamiasciurus hudsonicus*) in mature, mixed-species subalpine stands (Kendall and Arno 1990; Mattson and Reinhart 1994). Whitebark pine requires low- to moderate-severity fire to persist in these stands.

Small mammals—Some small mammals thrive in large patches of early seral vegetation; these include the Columbian ground squirrel (*Spermophilus columbianus*) and northern pocket gopher (*Thomomys talpoides*) (Ream and Gruell 1980). Stout and others (1971)

studied small mammal populations 3 years after fire on the Sundance Burn (Kaniksu National Forest). Heather vole (*Phenacomys intermedius*) and deer mouse (*Peromyscus maniculatus*) were plentiful. The authors concluded that red-backed vole (*Clethrionomys gapperi*), meadow vole (*Microtus pennsylvanicus*), and water vole (*M. richardsoni*) could not become well established for 5 to 10 years after a severe burn. Snowshoe hares (*Lepus americanus*) use the forest interior in winter; in summer, they rely on succulent herbaceous material (DeByle 1985), which is plentiful in early seral stands. Small carnivores may be attracted to recent burns (Ream and Gruell 1980).

Several species of small mammals, including gophers, mice, and hares, prolong early seral stages by damaging tree regeneration (Ream and Gruell 1980). Small mammals also alter burned sites in ways that increase long-term productivity; for example, they disperse spores of micorrhizae in the soil of burned areas. Pocket gophers and ground squirrels mix organic matter with mineral soil, improving soil aeration and reducing erosion potential (Ream and Gruell 1980).

Species associated with large patches of interior forest include the northern flying squirrel (*Glaucomys sabrinus*) and Townsend's big-eared bat (*Plecotus townsendi*). Severe fires would displace these species for many decades, but they use cavities in fire-created snags for nest sites. Red squirrels, which require cone-producing trees for food and cover, would be displaced after severe fire, at least until tree regeneration begins to reproduce (Ream and Gruell 1980).

Birds—Birds comprise more than half the vertebrate species of Idaho (fig. 3). Some bird species use several types of habitat and thus benefit from diverse cover types and structural stages. Others rely on large areas in one structural stage. Some require expanses of early seral stands that follow severe fire, and some require old growth stands that originated with severe fire or have been maintained by low-severity fire.

Cavity-nesting species require a unique habitat that is influenced in several ways by fire. A continuous supply of broken-topped snags is essential for cavity-nesting birds, which comprise a large proportion of the bird species in northern forests. Tree species preferred for cavities include ponderosa pine and western larch, both of which were favored by presettlement fire regimes (McClelland 1979). Snags are plentiful after severe fire, but large snags that had broken tops and decay before burning are used most heavily in the first years after fire (Hutto 1995; Saab and Dudley 1995). As decay softens the interiors of the remaining snags, they become increasingly accessible to cavity nesters. After severe fire, a new generation of trees must mature before the supply of snags can be replenished. Providing for cavity nesters thus requires attention to long-term patterns of snag fall and decay (Morrison and Raphael 1993). The abundance and longevity of large snags have been difficult to determine becauses snags have been considered a potential source of lightning fires and therefore removed from forests (Covington and others 1994). However, the forests of northern Idaho contain both western larch and western redcedar snags still standing more than 80 years after being killed by fire. Mixed-severity fire often produces patches of snags, the spatial pattern favored by cavity nesters (McClelland and Frissell 1975; McClelland and others 1979).

The early successional habitat created by severe fire contains unique features that are required by some bird species and favor abundance of others. Vegetation regrowth after fire generally results in rapid increases in arthropod populations, which in turn attract insectivorous birds (Saab and Dudley 1995). Fire increases potential nest sites for cavity nesters and shrub nesters (Hejl 1994). A study of severe burns in Montana (Hutto 1995) showed that several species were strongly attracted to early successional stands: Clark's nutcracker, mountain bluebird (*Sialia currucoides*), olive-sided flycatcher (*Contopus borealis*), black-backed woodpecker (*Picoides arcticus*), and three-toed woodpecker (*Picoides tridactylus*). Many of the abundant bird species were insectivores, feeding on snags of the species and sizes most used by beetle larvae after fire. Seed-eating species appeared to feed on seed in fire-opened cones. Standing dead trees provided nest sites for 22 percent of the 87 bird species observed. Abundance of two species—Townsend's solitaire (*Myadestes townsendi*) and white-crowned sparrow (*Zonotrichia leucophrys*)—was positively correlated with fire size.

Successional shrubfields, often containing tree regeneration, provide cover and food for many bird species. In burned clearcuts in northern Idaho (TSHE/CLUN, TSHE/GYDR, TSHE/ASCA, and ABGR/CLUN habitat types), low shrub cover had abundant killdeer (*Charadrius vociferus*), mountain bluebird, dusky flycatcher (*Empidonax oberholseri*), rufous hummingbird (*Selasphorus rufus*), and lazuli bunting (*Passerina amoena*) (Peterson 1982). Blue grouse (*Dendragapus obscurus*), American kestrel (*Falco sparverius*), and rufous-sided towhee (*Pipilo erythrophthalmus*) use shrubfields extensively during the breeding season (Peterson 1982; Zwickel and Bendell 1970). From late summer through winter, many species—including blue grouse and ruffed grouse (*Bonasa umbellus*), mountain bluebird, and thrushes—use berry crops (Martin and others 1951), which are often abundant in seral shrubfields.

Species that require old-growth forest may be adversely affected by fire exclusion. For example, the western bluebird (*Sialia mexicana*), flammulated owl (*Otus flammeolus*), and Lewis' woodpecker (*Melanerpes*

lewis) favor forests containing large, old ponderosa pine (Hutto 1995; McCallum 1994; Saab and Dudley 1995). Fire exclusion for many decades is likely to reduce habitat for these species by increasing tree density, favoring Douglas-fir over ponderosa pine, and reducing forb and shrub cover.

Species strongly associated with large expanses of old-growth, cedar-hemlock forest include brown creeper (*Certhia americana*), winter wren (*Troglodytes troglodytes*), and golden-crowned kinglet (*Regulus satrapa*) (Hejl and Paige 1994). Fire exclusion affects these species very little, although activities designed to reduce fuels or fuel continuity in such habitats could adversely affect them. Small fires and activities that increase forest edges may increase the abundance and effectiveness of nest predators and nest parasites (Hejl 1994; Paton 1994).

Aquatic Fauna—Stream ecosystems are closely linked to the surrounding terrestrial ecosystems, so fire can dramatically alter aquatic habitat. The stream microclimate is altered wherever streamside vegetation is removed (Lyon and others 1978). Severe fires also increase stream flow, initially removing but later adding sediment and woody debris. The extent of fire effects on streams depends on how much of a watershed is burned severely; thus effects on headwater streams are often much more dramatic than effects on higher order streams (Minshall and others 1989b).

A study of the effects of a large crown fire on cutthroat trout (*Oncorhynchus clarki*) habitat in a 4th- and 5th-order stream in central Idaho (Minshall and others 1989a) demonstrated the complexity of fire effects on aquatic ecosystems. During the first few postfire years, stream conditions were detrimental to trout in all life cycle stages. Survival of eggs and fry was reduced by heavy sediment loads and lack of suitable spawning beds. Aquatic food sources and adequate rest sites (pools, eddies, and debris jams) reached optimum levels within 15 years after fire. Terrestrial food sources and bank undercuts, important for overwintering, were reestablished within 25 years. Optimal conditions were expected to develop between 30 and 60 years after fire, and then decline because of heavy shading and reduced terrestrial detritus.

Amphibians and Reptiles—Fire effects on amphibians and reptiles of northern Idaho have not been described in the literature. Effects of fire depend on habitat and life history of the individual species.

Fire Effects and Fire Use: General Considerations

Natural fire regimes do not exist anywhere in northern Idaho today. Even in the Selway-Bitterroot Wilderness, which has one of the oldest wilderness fire management plans in the United States, fires burn less area than they did a century ago, and fire severity patterns have changed (Brown and others 1994). So what use is a description of the historic fire regime?

"Study of past ecosystem behavior can provide the framework for understanding the structure and behavior of contemporary ecosystems, and is the basis for predicting future conditions" (Morgan and others 1994a). A shifting mosaic of forests, burned at different times by fires of different severities, covered most of northern Idaho for many centuries prior to 1800. Although the exact fire regimes are difficult to determine and probably varied over time, they apparently were a part of a sustainable pattern. If management aims to retain or restore a particular mix of species or age classes in ecosystems historically dependent on fire, understanding of presettlement stand dynamics is essential. If enhancement of a particular species or habitat is the goal, the historic relationship of that species or habitat to fire should be considered. Landscape designs that depart from natural conditions risk failure because they may be in opposition to natural forces (Byler and others 1994; Everett and others 1994).

Actions that follow or mimic the successional pathways of presettlement forests are more likely to contribute to long-term forest health than are actions that produce landscapes rarely seen before the 20th century (Society of American Foresters 1993). This is not to say that presettlement ecosystems were necessarily stable. Even at very large spatial scales, ecosystems characterized by large, stand-replacing fires did not show constant proportions of cover types and structures over time (Turner and Romme 1994). Vegetation has changed constantly in response to climatic changes, geological events, species immigration, and patterns of human use (Johnson and others 1994). For example, pollen records from the Priest River valley indicate that western hemlock and western redcedar may have been important forest components for less than 3,000 years (Johnson and others 1994; Mack and others 1978). Because rates of change in presettlement times were usually slower than in recent times, characteristics of presettlement forests may not provide answers to management questions where rapid large-scale, long-term, or permanent changes have occurred. In northern Idaho, such changes include effects of fire exclusion, selective harvesting, white pine blister rust, and on some sites, erosion of the soil's fertile volcanic ash cap.

Planning Prescribed Fires

Prescribed fire is one means to accomplish resource management objectives. This section gives suggestions for using prescribed fire, although it is not a

complete guide for writing and carrying out prescriptions. Detailed methods for planning prescribed fires are presented in Fischer (1978, 1984) and Martin and Dell (1978). Brown (1984) focused on the overall planning process and how to merge experience with technical knowledge in designing fire prescriptions. The following paragraphs are based on all three reports, as well as other sources cited.

A successful prescribed fire must be executed safely, burn under control, disperse smoke in an acceptable manner, and attain resource management objectives. To be useful, fire objectives must be specific and quantitative, incorporating expertise from all pertinent resource disciplines. Fire objectives often include, but are not limited to, producing desired levels of overstory and understory mortality, duff removal, mineral soil exposure and protection, and woody debris reduction and retention. To meet management objectives in northern Idaho mixed conifer logging slash, Reinhardt and others (1991) suggested the following general guidelines:

Duff left unburned, percentage of original load	45-75 percent
Mineral soil exposed	15-40 percent
Small woody fuels (<3 inches) remaining	0-10 tons per acre
Large woody fuels (>3 inches) remaining	10-30 tons per acre

In the Northern Rocky Mountains, Harvey (1982) recommended clearing only as much mineral soil as necessary to meet desired objectives. Since the surface organic layers and buried rotten wood are important for maintaining soil structure and nutrient content, burning prescriptions should be selected to protect these soil components. Graham and others (1994) suggested burning when lower duff moistures exceed 100 percent (usually in spring). Recommendations for woody debris retention are discussed in "Coarse Woody Debris."

Specific prescribed fire objectives are determined by evaluating resource objectives and constraints, such as control and smoke dispersal needs, for individual sites. Season of burning may be a constraint for ecological and economic reasons. The area burned by nonlethal fire in the Selway-Bitterroot Wilderness apparently peaks in early August during most years; the area burned by stand-replacement fire peaks in mid- to late August. In 1988, area burned by both kinds of fire reached its maximum in early September (Brown and others 1994).

A fire prescription lists the weather conditions and fire behavior needed to achieve objectives and meet constraints. Successful prescriptions integrate site-specific data, technical aids, and experience. Prescribed fire planning requires knowledge of stand composition and structure; the amount, moisture, and distribution of fuels; site, duff, and soil characteristics; and temperature, humidity, and wind patterns for the site. The ignition pattern is chosen to control the way in which available heat energy will be released (Ryan 1990). Norum (1977) described the use of strip firing to control fireline intensity, flame length, and hence crown scorch in underburns. The relationship between flame length and crown scorch depends on wind speed and ambient temperature (Van Wagner 1973). Figure 4 shows a model of this relationship for midflame windspeeds of 5 miles per hour, an average value for prescribed underburns. To keep crown scorch under 60 feet when temperature is 50 °F, for example, flame length must be 10 feet or less. When the temperature is 80 °F, flame length must be under 8 feet.

Fire spread models form the foundation of several technical aids for predicting surface fire behavior, although one must recognize that current fire spread models do not incorporate the influence of firing techniques or nonuniform fuels on fire behavior. Rate of spread and flame characteristics can be estimated using the BEHAVE fire behavior prediction system (Andrews 1986; Andrews and Chase 1989). Fuel models can be developed for a specific site using BEHAVE (Burgan and Rothermel 1984). RXWINDOW (Andrews

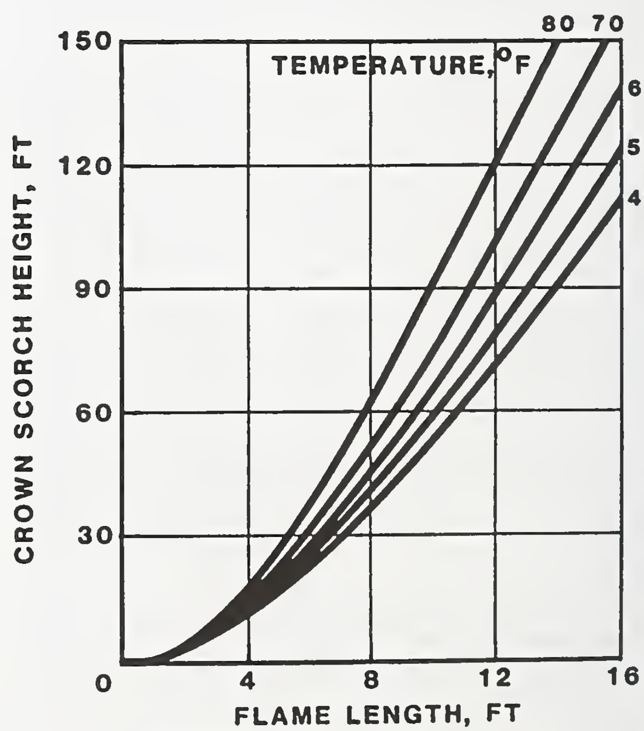

Figure 4—Relationship between scorch height, temperature, and flame length for prescribed underburns at midflame wind speeds of 5 miles/hour, from Reinhardt and Ryan (1988b).

and Bradshaw 1990) calculates ranges of environmental conditions that can produce a given range of fire behavior. RXWTHR and RXBURN (Bradshaw and Fischer 1981a, 1981b) use historic weather records to estimate the frequency with which a prescribed set of burning conditions is likely to occur. Rothermel (1991) described how to identify conditions in which severe fires can occur, and how to estimate spread rate, intensity, and size of crown fires. Estimates of surface fire characteristics, transition to crowning, and spotting potential are integrated in the Fire ARea SImulator (FARSITE model) being developed and tested on prescribed natural fires (Finney 1994).

Technical aids are also available for predicting duff consumption and mineral soil exposure. The predictions given here were developed using data from Deception Creek Experimental Forest in northern Idaho (Brown and others 1991; Reinhardt and others 1991). Duff depth reduction was positively correlated with preburn duff depth and negatively correlated with preburn duff moisture (fig. 5). On a site with duff 1 inch deep, for example, burning when duff moisture averages 80 percent of oven-dry weight will consume about 0.5 inch of duff. If preburn duff is 3 inches deep, about 1.5 inches will be consumed. This corresponds to roughly half of the preburn duff load (fig. 5, 6); such a burn would expose mineral soil on approximately 30 percent of the site (fig. 6).

Figures 5 and 6 can be used "backwards" to estimate a range of duff moistures with which fire objectives can be met. If 20 to 30 percent mineral soil exposure is desired, for example, burning should be conducted

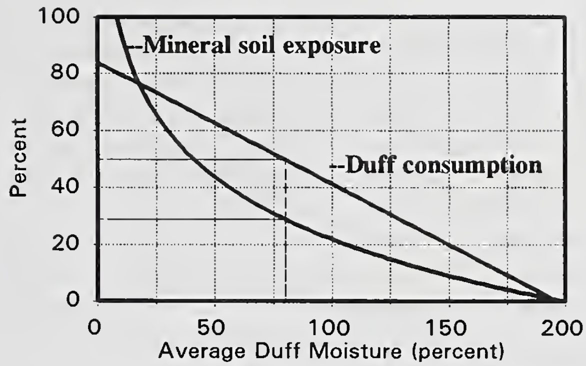

Figure 6—Relationship of duff moisture content to percent duff consumption (diagonal line) and percent mineral soil exposure (curved line). From equations 1 and 6 in Reinhardt and others (1991). The dashed lines refer to an example given in the text.

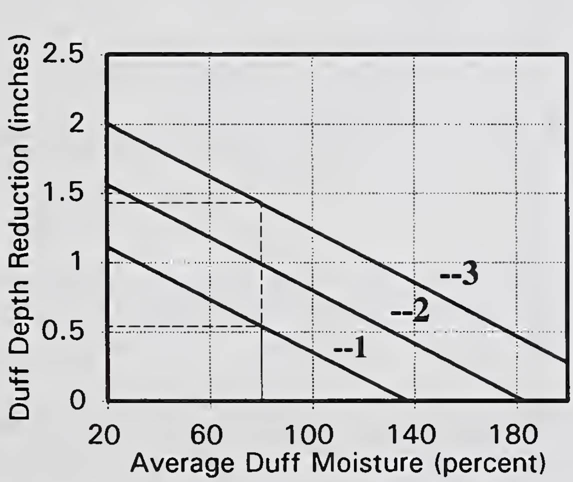

Figure 5—Relationship of duff moisture content to duff depth reduction (inches). Diagonal lines correspond to preburn duff depths of 1, 2, and 3 inches. From equation 3 in Reinhardt and others (1991). The dashed lines refer to an example given in the text.

when duff moisture averages 80 to 110 percent. The relationships shown in figures 5 and 6 are best suited for use in mid-elevation forests of Fire Groups Seven and Eight, where average duff depth ranges from 0.5 to 4.5 inches and duff moisture is greater than 20 percent. If duff is less than 0.4 inch deep, it is as effective a seedbed as bare mineral soil (Brown and others 1991). Fuels are deeper and drier beneath tree crowns than throughout a stand, so predictions based on overall stand conditions or fire danger rating systems may underpredict fire severity at the bases of trees (Ryan and Frandsen 1991).

A computer model, the First Order Fire Effects Model (FOFEM) (Keane and others 1994b; Reinhardt and others 1995), uses the relationships shown in figures 5 and 6, as well as other models, to predict immediate effects of fire on several ecosystem components. These include duff and woody fuel consumption, mineral soil exposure, and smoke production for burns in forest stands and some shrub-dominated communities. FOFEM also estimates tree mortality. A planning simulator computes the burning conditions needed to achieve various effects. FOFEM is available in a personal computer version or through the Fire Effects Information System (Fischer and others 1996).

Data and models are tools for planning fire prescriptions, but they can be applied best when combined with experience. Reinhardt and others (1989) are developing an expert advisory system for integrating experience with technical aids to plan prescribed fires. Kilgore and Curtis (1987) interviewed the staffs of 12 National Forest districts experienced in understory burning to produce "Guide to Understory Burning in Ponderosa Pine-Larch-Fir Forests in the Intermountain West." The people interviewed relied on their own

experience and that of others, especially those who have worked extensively in the vegetation types to be burned. They describe the objectives, prescriptions, and techniques being used, and relate burning season and techniques to costs. Information from this report is applicable mainly to underburning in northern Idaho Fire Groups One and Two. A report by Gruell and others (1986), on burning in grasslands in Montana that are being invaded by Douglas-fir, may also be useful for fire management planning in northern Idaho Fire Groups One and Two.

After a fire prescription has been developed, the burning plan describes exactly how the prescribed fire behavior is to be produced. After burning, a record of the fire provides a reference for future planning.

Fuels

Fire spread, fire duration, and soil heating are strongly related to fuel loading and fuel moisture. Fuels are classified according to size, condition, and vertical location. Fine surface fuels strongly influence fire spread and intensity, but have little effect on soil heating. Large fuels and duff contribute to both upward and downward heat pulses and prolong the duration of fire (Hungerford and others 1991). Many fires of the 19th and early 20th centuries consumed most of the fuels present, suggesting that presettlement intervals between fires were short enough to prevent heavy accumulations of fuels (Hungerford and others 1991).

Estimates of fuel properties are required to accurately predict fire behavior (Albini 1976; Burgan 1987; Burgan and Rothermel 1984) and fire effects (Keane and others 1994b; Reinhardt and Ryan 1989). But fuel loadings vary greatly from site to site, even within groups of similar habitat types. Brown and See (1981) found that total downed woody fuel loading in the Northern Rocky Mountains was positively correlated with potential forest yield capability, although great variation occurred within groups of habitat types. They listed the habitat type series that occur in northern Idaho, from lowest to highest fuel loadings, as follows: whitebark pine, Douglas-fir, subalpine fir, grand fir, western redcedar, and western hemlock. Brown and Bevins (1986) attempted to relate loadings of litter, 0 to 1 inch woody fuels, herbs, and shrubs to specific fire groups for Montana (Fischer and Bradley 1987; Fischer and Clayton 1983), but found that variation within fire groups was greater than differences between groups. When knowledge of potential fire behavior for a particular site is needed, to run BEHAVE, for example, a fuel model (Anderson 1982) is often the best way to quantify fuels. For estimating first order fire effects using FOFEM, fuel measurements from the site are most useful (Reinhardt 1993).

Fuel moisture and condition (green versus cured, sound versus rotten) are at least as important to fire behavior and effects as fuel quantities (Albini 1976; Hungerford and others 1991). Fuel moisture and condition are related to elevation, aspect, and season (Brown and Bevins 1986), which are reflected to some extent in habitat types and, therefore, fire groups. Where fuel loadings are relatively heavy and often dry (as is likely to occur in Fire Groups Two and Four, for example), severe fires tend to be more frequent than where fuels are sparse (Fire Group One) or usually moist (Fire Groups Five and Nine). Relationships between habitat types and fire regimes are discussed in more detail within the fire groups.

Fuel loadings follow few discernible successional patterns. After a severe fire in seral lodgepole pine in western Montana, few snags fell for 2 years (fig. 7). After 15 years, standing snags were reduced by 85 percent; after 21 years, nearly 93 percent of all snags had fallen (Lyon 1977, 1984). When woody fuel loadings increase because of mortality from fire or other causes, potential fire severity increases. There is little evidence, however, that heavy postfire fuels increase the likelihood of ignition or fire spread (Anonymous 1931). Brown and See (1981) found two patterns in forest fuel loadings in succession: (1) until the trees in a stand begin to decline in vigor and soundness, fuel

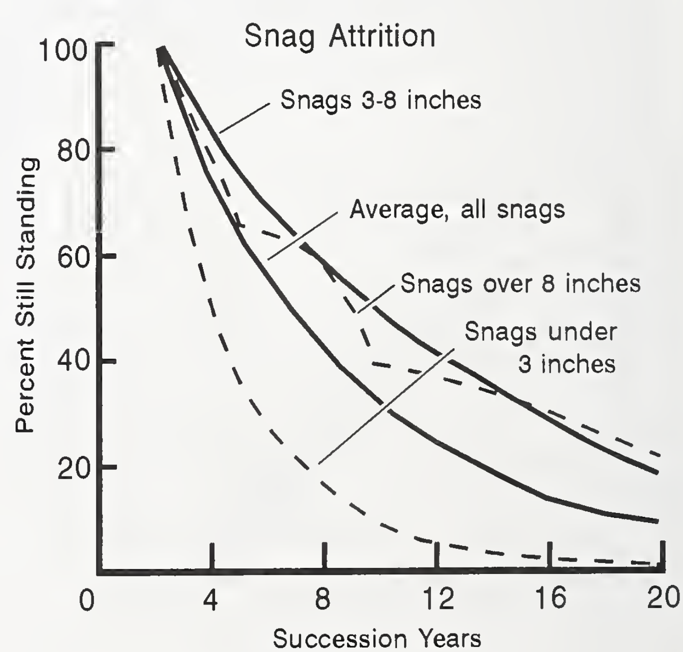

Figure 7—Percentage of lodgepole pine snags still standing, by year and diameter class, Sleeping Child Burn, Bitterroot National Forest, MT, 1962 to 1982 (Lyon 1984).

quantities cannot be predicted; and (2) fuel quantities become high as trees begin to decline.

Untreated logging slash represents a significant fire hazard in northern Idaho forests because dead and downed woody fuel loadings on harvested sites can greatly exceed those on pretreatment stands. This increased hazard persists for at least 3 to 5 years, even with compaction from winter snows. Potential fire behavior in slash of several species was evaluated experimentally (table 7). After 1 year, potential spread rates decline least rapidly for western white pine, lodgepole pine, and western redcedar. Actual spread is often faster in cedar slash than this comparison indicates because cedar slash loadings are often very heavy and the material deteriorates slowly. Actual spread in western larch is usually much slower than in this comparison because operational loadings tend to be lighter than those used in the experiments. In addition, western larch foliage in slash responds more rapidly to moisture change than foliage of other northern Idaho conifers. Ponderosa pine, western white pine, subalpine fir, and Douglas-fir are intermediate in responsiveness. Lodgepole pine, Engelmann spruce, western redcedar, and grand fir responses are slowest (Anderson 1990).

Coarse Woody Debris

Coarse woody debris (woody residue larger than 3 inches in diameter, according to Graham and others 1994), is a part of the fuel complex, but its role in forest ecosystems is complex enough to warrant separate discussion. Coarse woody debris stores nutrients and water and controls their flow through the ecosystem; contributes to the structural complexity of the standing forest, surface materials, and soil; provides a mechanical impediment to erosion; and provides habitat for fungi, saprophytes, orchids, and small animals (Edmonds 1991; Evenden 1990; Graham and others 1994). Combustion of coarse woody debris strongly influences soil heating during fire and also contributes to fire intensity, influencing aboveground fire effects (Hungerford and others 1991).

Table 7—Rankings of slash from northern Idaho tree species in regard to relative flammability (Fahnestock 1960).

Spread rate group	Species	Age of slash
1 (fastest)	LAOC	Fresh
2	PIMO,PICO,THPL,PSME, TSHE,ABGR	Fresh
3	PIPO,PIEN	Fresh
	PIMO,PICO,THPL	1 year old
4	PIPO,PSME,TSHE,PIEN	1 year old
5 (slowest)	ABGR,LAOC	1 year old

In unmanaged stands, coarse woody debris follows a cycle that originates in tree mortality, is followed by the deterioration and fall of snags, and ends in the decay of woody debris and its incorporation into the soil. Fire causes a pulse of mortality that increases the supply of snags and downed logs to insects, small mammals, birds, and fungal decomposers (Edmonds 1991). Decaying large logs act as reservoirs for mycorrhizae and nitrogen-fixing bacteria, which can reinoculate a site after disturbance and continue providing nitrogen for many decades (Graham and others 1994).

Snags and downed logs are important to wildlife for feeding, cover, and reproduction. In the Blue Mountains of Oregon, with vegetation that resembles the drier habitat types of northern Idaho, 37 species of birds and mammals reproduce in tree cavities at least some of the time (Thomas 1979). Three bird and nine mammal species use downed logs for cover, feeding, or reproduction (Maser and others 1979). In western Montana, cavity-nesting birds comprise 25 percent of the breeding bird species (McClelland and others 1979).

While snags are somewhat ephemeral components of forest structure, coarse woody debris can persist for centuries (Graham and others 1994; Maser and others 1979). Burning accelerates the loss of bark, an important habitat itself, but may retard further animal use of woody debris. Burning hardens outer wood, slowing decomposition and making the wood more difficult to excavate.

Large logs retard water movement, slowing erosion; logs oriented across the slope provide more soil protection than those oriented perpendicular to the contour (Maser and others 1979). Large logs also provide shade that enhances establishment and growth of some seedlings. Large accumulations of deadfall or logging slash can affect the behavior of large mammals. Elk use declines when the depth of dead and downed material or slash exceeds 1.5 feet (Boss and others 1983). As logs decompose and become incorporated into the soil, their high water-holding capacity favors regeneration and seedling establishment, especially on dry sites and where competition is intense (Page-Dumroese and others 1991). Residual organic matter, including woody debris, also protects the soil from raindrop impact.

Fire prescription objectives should include conservation of snags and woody debris, especially on droughty or otherwise harsh sites. Abundant snags provide shelter for seedlings, animal habitat, and retention of nutrients. The dead trees standing after severe fire are the only source of snags or woody debris on the site until the next generation of forest matures. Preference

in snag retention should be given to large snags and those with decay or cavities prior to burning.

The consumption of large fuels by fire is variable, depending in part on moisture content, soundness, and spatial arrangement (Hungerford and others 1991). Prescriptions for reducing fine fuels can be tailored to conserve coarse woody debris by incorporating the length of time elapsed since extended precipitation (Maser and others 1979). According to Harvey (1982), between 10 and 15 tons per acre of downed woody material greater than 6 inches in diameter should be left to protect soil productivity. Amounts of coarse woody debris recommended for retention after timber harvesting vary according to habitat type (Graham and others 1994); levels for habitat types occurring in northern Idaho are discussed in individual fire groups. Very heavy quantities of woody debris (in excess of requirements for protecting soil) increase the potential for severe fire, which can reduce the soil's mineral and organic reserves dramatically (Mandzak and Moore 1994).

Predicting Fire-Caused Tree Mortality

Fires can damage trees in several ways: foliage mortality, bud kill, bole and cambium damage, and root damage. Mortality often results from the effects of a combination of fire-induced injuries. As described above, "Relationships of Major Tree Species to Fire," trees of different species vary in their resistance to fire. Engelmann spruce and subalpine fir, for example, have low to moderate survival rates after patchy burns of low severity (categories 1-U, 1-L, 2-U, and 2-L in fig. 2). They survive more severe fires only occasionally (Ryan 1995). In contrast, survival of large western larch is moderate even after fires in the 4-M and 5-M categories; occasionally, large western larch survive fires of 4-D and 5-D severity. Susceptibility to fire damage varies with tree vigor, size, and season of burning (Harrington 1993; Simmerman and others 1991; Wyant and others 1986). Tall trees have a large proportion of their foliage above scorch height and often have thicker bark than shorter trees, so they are more resistant to fire. Damage from fire can alter a stand's susceptibility to insects and diseases, leading to indirect mortality. Amman and Ryan (1991) recommended that existing models for predicting fire-caused tree mortality be used with caution, especially in areas of mixed-severity fire near the edges of severely burned forests.

Heating of the tree crown kills both foliage and buds. Lethal levels of crown scorch change to some extent with the season, since buds may be more sensitive to heating in spring than fall, and the tree's nutrient reserves are more readily depleted during the growing season than during dormancy. General guidelines for controlling crown injury were described by Ryan (1990). To encourage postfire survival and growth of mature trees, prescribed fires should leave a live crown ratio of at least 0.4. In vigorous young trees, a crown ratio of 0.3 may be satisfactory. If the prefire crown ratio is less than this, the prescription should keep scorch height below the bases of tree crowns.

Bark thickness is the best indicator of a tree's resistance to stem injury from fire. In most natural fuels, bark must be at least 0.5 inch thick to minimize serious cambium injury (Ryan 1990). When bark is thicker than 1.5 inch, less than 5 percent of the cambium is usually killed. However, if heavy woody fuels are burned on more than one side of a tree (within 3 feet), stem damage can be lethal.

Root injury slows growth and makes trees susceptible to infection, moisture stress, and windthrow. Most fine roots and their micorrhizae are found in surface humus and upper mineral soil, so burning the humus and heating the soil can injure these structures (Ryan 1990). Coarse roots grow in mineral soil, although they may grow in the upper mineral soil under deep duff. Root injury is usually minimal when lower duff moisture is greater than 120 percent, or when fire consumes less than 1.5 inches of duff. If more than 4 inches of duff are consumed, most trees suffer some basal or root injury. If duff is deeper than 4 inches and drier than about 35 percent, all but the thickest-barked trees are likely to be damaged by basal girdling. Duff is deeper and drier under large trees than in the open, so even old trees with very thick bark are vulnerable (Ryan and Frandsen 1991; Swezy and Agee 1991). Fire retardant chemicals applied to fuels under leave trees may provide a small amount of protection. Ryan and Steele (1989) found that clearing large woody fuels from within 3 to 4 feet of the bole did not provide significant protection.

A series of nomograms has been designed to help managers estimate fire damage according to tree species and characteristics (fig. 8). Data were collected 3 to 8 years after burning, so some mortality due to postfire insects and diseases was measured along with direct fire damage. The nomograms show mortality levels for Douglas-fir, Engelmann spruce, lodgepole pine, subalpine fir, western hemlock, western larch, and western redcedar. To predict fire-caused damage for grand fir and western white pine, use the line for Engelmann spruce and western redcedar (Reinhardt 1993). The authors explain how to use the nomograms to develop a fire prescription for 20 percent mortality in Douglas-fir leave trees averaging 17 inches in diameter, 100 feet tall, with a live crown ratio of 0.5:

> Entering the nomogram at the lower left at observed tree diameter, draw a horizontal line until you intersect the correct species line. Then turn a right angle and draw a line straight up...until it intersects the target mortality rate

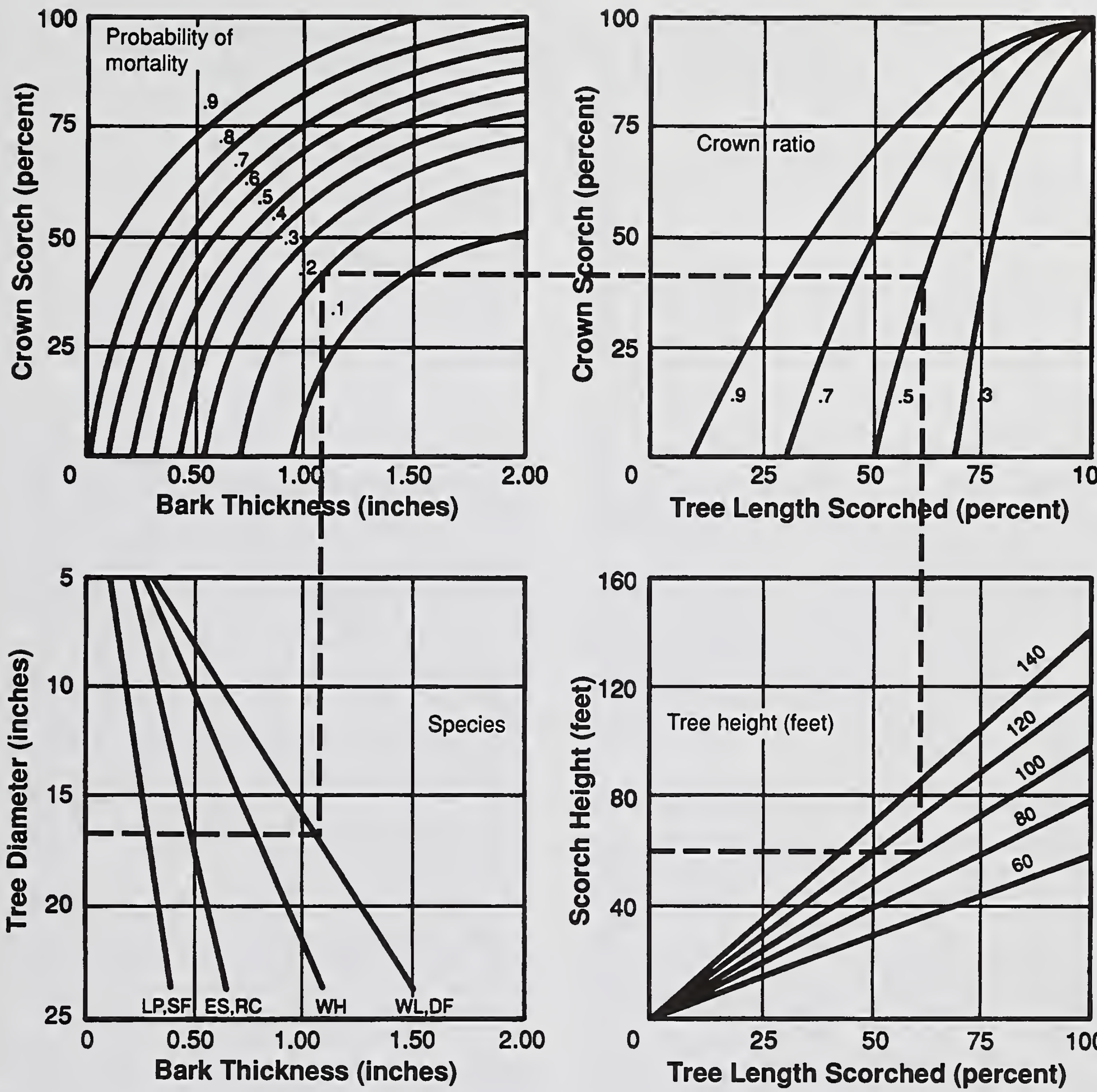

Figure 8—Tree mortality nomogram for use in prescription development, from Reinhardt and Ryan (1988b). LP identifies lodgepole pine; SF, subalpine fir; ES, Engelmann spruce; RC, western redcedar; WH, western hemlock; WL, western larch; and DF, Douglas-fir. Dashed lines are for an example given in the text.

curve (0.2). At this point, turn a right angle again, to the right. This time, when passing from the upper left to the upper right quadrant, it is possible to read off crown volume scorched (percent). This example shows that a little more than 40 percent of the crown volume of these trees may be scorched without exceeding the target mortality of 20 percent....

To convert percentage crown volume scorched to scorch height...[make] a right angle turn down [from] the curve representing the appropriate crown ratio, and then continue down to the appropriate tree height curve. Make another right angle turn to the left. Read allowable scorch height (in this example 60 feet...) off the vertical axis of the lower right quadrant. This is the maximum scorch height that can be had and still limit the mortality to the desired level.

Ponderosa pine is not included in figure 8. Research in southwestern Colorado (Harrington 1993) showed that the probability of mortality in ponderosa pine was related to tree diameter, crown scorch, and the season of burn (table 8). This study was carried out in a

Table 8—Estimated probability of fire-caused mortality (percent) for ponderosa pine in southwestern Colorado in four d.b.h. classes, three crown scorch classes, and two seasons (Harrington 1993). Bole damage from fires was minimal.

Season	Crown scorch	D.B.H. (inches) 3.0 (1.5-4.4)	5.9 (4.5-7.3)	8.9 (7.4-10.3)	11.8 (10.4-13.3)
		Percent			
	50	3	2	1	1
Dormant	90	31	4	6	2
	100	71	47	24	10
	50	32	14	6	2
Growing	90	79	57	32	14
	100	95	88	72	48

vigorous stand of climax ponderosa pine; results are applicable to sites in Fire Groups One and Two in northern Idaho. Information is sparse on ponderosa pine's response to crown scorch in the more moist fire groups (Harrington 1994).

Fire effects often interact with other stresses to produce mortality. Simmerman and others (1991) reported that mortality in small ponderosa pine (less than 10 inches d.b.h.) was greater than mortality in small Douglas-fir after thinning and underburning because the pines had been more stressed while growing under the closed canopy.

Insects and Diseases

Like fires, infestations of native insects and diseases occurred in northern Idaho with a variety of severities, at a variety of time intervals, throughout many centuries prior to settlement by Euro-Americans. Forest ecosystems are assumed to be resilient to disturbance by native insects and diseases, just as they are assumed to be resilient to disturbance by presettlement fire regimes (Habeck and Mutch 1973; Hungerford and others 1991; Jurgensen and others 1994). Forest composition, structure, and successional patterns were produced by the interactions of all disturbances over time. Root disease, for instance, probably contributed to the historic dominance of western white pine after fire by reducing Douglas-fir and grand fir early in stand development. Root disease may have also favored western larch on sites where it was not eliminated by competition with western white pine (Hagle 1995).

Resilience to disturbance cannot be assumed for forests affected by nonnative insects and diseases. The most influential disturbance in the forests of northern Idaho in this century, other than fire, has been white pine blister rust. Blister rust has been a major contributor to the loss of western white pine as the dominant seral species over much of northern Idaho (Covington and others 1994), and is currently causing a severe decline in whitebark pine (Keane and Arno 1993). In seedling and sapling stands, blister rust causes high mortality; in mature forests, it causes low cone production. Heavy loadings of surface fuels and increased hazard of severe fire occur where mortality is high. Profound differences between blister rust and native pathogens become evident in stand development following an epidemic, because blister rust-infected pines have very limited ability to regenerate. Although increases in resistance can be achieved in one generation of western white pine, widespread natural regeneration by rust-resistant varieties may be very slow (Byler and others 1994). Although rust-resistant individuals of whitebark pine can be found, the extremely slow growth of this tree on high subalpine sites will limit recovery.

Fire exclusion, especially where combined with blister rust, has contributed in the forests of northern Idaho to an increased proportion of Douglas-fir and grand fir which are less resistant to root disease than pine species and western larch (Thies and Sturrock 1995). It has also led to increased structural homogeneity over large areas and increased occurrence of multi-storied stands (Covington and others 1994). These changes favor epidemics of defoliating insects and increased area infected by root disease and stem decay, which may enhance bark beetle populations (Carlson and Wulf 1989; Filip and others 1983; Mutch and others 1993; Wellner 1984). Dense tree regeneration and heavy fuels resulting from disease- and insect-caused mortality increase potential fire severity (Hungerford 1991; Mutch 1992). Where root disease delays canopy closure and perpetuates regeneration, increased accumulations of large fuels are less likely.

Bark beetles prefer stressed trees to vigorous trees, especially in dense stands where the target species dominates. Douglas-fir is most susceptible to Douglas-fir beetle (*Dendroctonus pseudotsugae*) in old, dense stands. Ponderosa pine is most susceptible to western

pine beetle (*D. brevicomis*) in large, old trees. Mountain pine beetle (*Dendroctonus ponderosae*) prefers dense, mid-size trees. In lodgepole pine, mountain pine beetle is most likely to reach epidemic proportions when stands contain a high proportion of large diameter trees and growth rates begin to decline. In southern British Columbia, this occurs after the majority of trees are 10 inches d.b.h. or greater (Safranyik and others 1975; Shrimpton and Thomson 1983).

Understory fires that thin stands may reduce bark beetle populations. Results of research concerning postfire effects on bark beetle populations are mixed. Safay (1981) described ponderosa pine stands in the PSME/PHMA habitat type in Benewah County, ID, that were burned with low-intensity prescribed fires. Fires had average flame lengths of about 20 inches and produced average crown scorch of 13 percent. Pines on burned sites were no more likely to be subsequently attacked by bark beetles (*D. ponderosae*, *D. brevicomis*, and *Ips pini*) than were those on unburned sites. In locations where 30 percent or more of the duff was removed, overwintering habitat for pine engraver beetles may have been significantly reduced. In Yellowstone National Park, pine engraver and Douglas-fir beetles preferred fire-injured trees to uninjured trees (Amman and Ryan 1991). The likelihood of postfire damage by bark beetles depended on prefire populations and extent of cambium injury (Rasmussen and others 1996). If increased insect activity is detected on a burned site, removal of the severely scorched trees may limit insect proliferation.

Root disease fungi have persisted for millennia in forests shaped by fire. Most studies indicate that mycelia of *Armillaria* species are found primarily within host tissue (Redfern and Filip 1991), relatively isolated from direct influences of fire and other fungi. Fires perpetuate dominance by tree species that are resistant to both fire and root disease, especially the pine species and western larch. Fires also reduce the modal size of dead roots and logs, which harbor mycelia of laminated root rot (*Phellinus weirii*) in mountain hemlock stands (Dickman and Cook 1989). Conditions ideal for the spread of root and stem disease tend to develop in forests where fire exclusion and selective logging have increased dominance by Douglas-fir and the true firs. Hagle and others (1992) found root disease symptoms visible in aerial photographs of 96 percent of a random sample of Douglas-fir and grand fir stands on the Fernan and Wallace Ranger Districts of the Idaho Panhandle National Forests. In most stands, disease severity was rated moderate to low, but 12 percent of the stands had very severe root disease that left little forest canopy. In a random sample of commercial forest lands on the Nez Perce National Forest, Hagle and Byler (1994) found some effect from root disease in 96 percent of 776 stands; most of the disease was rated moderate in severity. Based on measured changes in forest age and species composition, they concluded that the commercial forest land on the Nez Perce National Forest has had a significant increase in root disease severity over the 85 year period from 1900 to 1985.

Fire damage to trees can increase damage from fungi. In south-central Oregon, fire-damaged roots of lodgepole pine had more decay caused by brown cubical butt rot (*Phaeolus schweinitzii*) than did undamaged roots (Gara and others 1985). Fire damage to the boles of grand firs can activate Indian paint fungus from a dormant state (Aho 1977). Dickman and Cook (1989) suggested that stands with average fire return intervals of less than 200 years in the mountain hemlock forests of the Cascade Mountains, OR, have smaller woody debris and, therefore, less inoculum of laminated root rot than stands with longer fire-free intervals.

Western spruce budworm (*Choristoneura occidentalis*) outbreaks occur with medium frequency in forests south and east of Moscow in northern Idaho, and with low frequency in forests north and west of Avery (Kemp 1985). Low outbreak frequencies occur in areas with high levels of volcanic ash in the soil. Spruce budworm outbreaks occurred near Priest Lake, ID, in 1922 (Fellin and others 1983). An outbreak was recorded in 1924 on the Clearwater, Nez Perce, and Coeur d'Alene National Forests. Since aerial survey techniques were developed in 1942, one other significant outbreak has been recorded in northern Idaho in the early 1970's (Stipe 1987). Spruce budworm defoliation produces some tree mortality, primarily in understory seedlings and saplings, and causes topkill in mature trees; but there have been few lasting effects of budworm defoliation in forests of northern Idaho. Where fire exclusion has increased the proportion of dense and multi-storied stands throughout the Northern Rocky Mountains, it has probably increased susceptibility to spruce budworm (Carlson and others 1983). Low-severity fire reduces the amount of understory host for budworm and can thus reduce a stand's susceptibility to infestation (Carlson and Wulf 1989).

Fires have probably limited the extent of dwarf mistletoe infestation in North American forests for thousands of years (Alexander and Hawksworth 1975; Covington and others 1994). Where tree growth rates are reduced due to fire exclusion, mistletoe growth is also reduced; the geographic extent of mistletoe, however, may expand. Moderate and severe fires have been used to reduce mistletoe in western larch stands in western Montana (Antos 1977) and in young ponderosa pine stands in central Oregon (Koonce 1981). Even if mistletoe is removed by fire, slow reinfestation occurs wherever it remains near the burn edge. Low-severity fire can activate mistletoe infection by releasing the host, providing a vigorous source of infection for regeneration (Knutson and Tinnin 1980).

Effects on Soils and Hydrology

Forests in the Northern Rocky Mountains depend on decomposition by both biological organisms and fire to recycle and regulate nutrients. The soils of northern Idaho have apparently remained productive through centuries of recurring fires (Hungerford and others 1991), but continued fertility is not guaranteed. Timber harvesting, grazing, and fire exclusion have altered the soil environment. Hungerford and others (1991) summarized some of these effects: In warm, dry environments (Fire Groups One and Two in northern Idaho), frequent low-severity fires in presettlement times maintained low fuel loads and caused minimal soil heating. Timber harvesting increases fuel loads on these sites. Even though most prescribed burns are of low to moderate intensity, more fuel is usually consumed than in presettlement times, so fire effects on soils can be more severe. In contrast, the fires that influenced moist habitats in presettlement times (Fire Groups Five, Seven, and Nine in northern Idaho) were severe in many locations and probably caused extensive soil heating. Since prescribed burns are not conducted during the extremely dry conditions that led to wildfire in the past, they probably have less effect on soils than did presettlement fires.

Fires can change the productivity of forest soils by altering both nutrient levels and soil structure, which interact to control soil productivity. Effects depend on soil moisture, soil temperature regime during burning, and the extent to which duff and large woody fuels are removed (Harvey and others 1989, Little and Ohmann 1988). Nutrients, especially nitrogen, are often limiting to tree growth in forests (Harvey and others 1994; Wenger 1984). Fire transforms organic nitrogen to its mineral form, which is either volatilized and lost from the site or condensed in the soil and thus made available to early successional plants (Jurgensen and others 1981). After "cool" fires in Douglas-fir and western larch, Jurgensen and others (1981) found that available nitrogen increased within a few weeks, but returned to preburn levels within 1 year. In burns under Douglas-fir and western larch cover, Stark (1977) found that levels of potassium, calcium, and phosphorus in the soil increased. Increased availability of these nutrients enhances the environment for microbial mineralization and fixation of nitrogen (Harvey and others 1989). Fires that remove most organic matter, however, can cause severe declines in microbial mineralization (Niehoff 1985). Harvey and others (1994) suggested that the risk of soil degradation by fire should be weighed against the certainty of eventual nutrient limitation in environments from which fire is excluded.

Like fire effects on nutrient levels, effects on soil physical properties depend on fire severity. Low-severity fires leave much of the duff layer intact and produce little temperature change in the soil. They also redistribute organic matter from duff and fuels into the soil, enhancing nutrient availability and possibly moisture-holding capacity (Harvey and others 1989). Complete duff removal, however, increases raindrop impact on soil, which decreases soil porosity and moisture absorption (DeByle 1981). When organic matter within the soil is consumed by fire, the soil's moisture-holding capacity declines (Neal and others 1965). High soil temperatures during fire (greater than approximately 750 °F) can cause aggregation of clay particles, increasing coarseness and making the soil less productive (Wells and others 1979). Although a water-repellant layer occasionally forms in severely burned soils, this problem is unusual in northern coniferous forests (DeByle 1981; Wright and Bailey 1982).

Prevention of erosion is another important consideration for fire managers. Fires of low and mixed severity caused little erosion after a spring broadcast burn on a clearcut in northern Idaho; the preharvest forest contained western hemlock, grand fir, western white pine, western larch, and Douglas-fir (Robichaud and others 1994). Low-severity fires also leave most large woody material to be converted to soil wood as it decays. If any erosion does occur on low-severity burns, however, the nutrient-laden surface soils are the first to be lost (Hungerford and others 1991). Large, severe fires pose greater risks of erosion until vegetation cover develops and detritus begins to accumulate (Lyon 1966). Extensive overstory mortality increases the likelihood of soil movement because it increases the frequency of rain-on-snow events and decreases fine root biomass in the soil (Agee 1993). Management-ignited fire can be combined with other management activities to decrease the risk of large, severe fires.

Potts and others (1985) used the sediment yield model for the USDA Forest Service Northern Region (Cline and others 1981) to predict sedimentation after burns of varying sizes; their results for a Douglas-fir cover type are shown in table 9. The model indicates that fires produce large increases in sediment mainly on large burns and on steep slopes. Where harvesting is conducted after wildfire, most predictions of sediment change increase by a factor of two or more.

No models currently relate sediment production to specific levels of fire severity, but an erosion prediction model is being adapted for forest planning in the mountains of the Western United States (Elliot and others 1994). The model incorporates effects of timber harvesting, site preparation, and road construction on estimates of snowpack, snowmelt, runoff, and sediment production. Where fire effects can be approximated by descriptors of timber harvest and site preparation, this model may be useful for fire management planning. Experiments conducted in preparing the

Table 9—Estimated changes in sediment yield during the first year after fires of various sizes for most cover types in the northern Rocky Mountains (Potts and others 1985).

Annual precip.	Slope	Annual preburn sediment yield	Postburn increase in sediment yield: No salvage logging 30 acre	380 acre	2,800 acre	Roaded & salvaged 30 acre	380 acre	2,800 acre
Inches	*Percent*	*T/mile²*	Percent					
15	20	10.2	0	6	81	81	93	213
	60	19.2	3	17	160	70	90	286
	90	48.6	1	17	150	37	55	216
30	20	11.5	0	5	72	72	83	187
	60	22.4	3	14	137	60	77	246
	90	53.8	1	15	136	33	50	195
45	20	17.9	0	3	46	46	53	121
	60	35.6	2	9	86	38	49	154
	90	76.2	1	11	96	23	35	138

model showed that low-severity burns for site preparation produced less than half as much sediment as high-severity burns (Robichaud and Waldrop 1992).

Mass movement is likely to occur after disturbance on slopes with excessive soil moisture. Pole and Satterlund (1978) suggested that ferns and other moist-site species, growing vigorously on open slopes (with coverage of 10 percent or more), can serve as indicators of sites with high risk of mass movement because they are indicative of high levels of soil moisture. In the Clearwater National Forest, the following plant species have been identified as indicators of instability for open slopes in Fire Group Eight:

Adiantum pedatum	*Listeria convallarioides*
Alnus sinuata	*Polystichum munitum*
Athyrium filix-femina	*Senecio triangularis*
Boykinia major	*Streptopus amplexifolius*
Equisetum arvense	*Trautvetteria caroliniensis*
Gymnocarpium dryopteris	*Veratrum viride*
Habenaria species	

Increased erosion on recent burns is often accompanied by increased water yield. Fires that remove 50 percent or more of the tree cover from a stand increase water yield significantly, and fire-caused increases persist as long as 25 years. The Water Resources Evaluation of Non-Point Silvicultural Sources (WRENSS) has been adapted to estimate the hydrological effects of various fire management strategies for forests of the Northern Rocky Mountains (Potts and others 1985). For sites with Douglas-fir cover that receive less than 20 inches of precipitation per year, WRENSS predicts little or no increase in runoff; such sites would be represented by the driest locations in northern Idaho (Finklin 1983, 1988; Finklin and Fischer 1987). For sites in the Douglas-fir cover type receiving more than 20 inches of precipitation per year, the model predicts that water yield in the first year after fire could increase as much as 29 percent (table 10). Predicted increases in water yield were similar for all major forest cover types in the Northern

Table 10—Estimated preburn water yield and percent increase during the first year after fire, according to percent basal area removed (Potts and others 1985).

Annual precipitation	Aspect	Annual preburn water yield	Postburn increase in water yield: 50 b.a. removed	90 b.a. removed	100 b.a. removed
Inches		*Acre-ft/acre*	Percent		
30	North	1.4	1	10	19
	East, west	1.2	4	12	20
	South	1.0	9	19	29
45	North	2.5	2	8	15
	East, west	2.3	2	7	13
	South	2.1	5	10	16

Rocky Mountains except lodgepole pine, for which predicted increases were lower.

Water yield from the Pack River drainage in the Kaniksu National Forest was monitored for 15 years after the Sundance Fire, which burned 26 percent of the watershed (Campbell and Morris 1988). The net effect of the fire on water yield was not clear because annual precipitation decreased. Seasonal streamflow patterns changed significantly after the fire, however. Peak runoff, which occurred in June during most prefire years, tended to occur in March during the 15 years following the fire.

Effects on Air Quality

Smoke emissions are subject to regulation because of their potential adverse impacts on visibility and human health. Adverse effects are amplified in mountain valleys during temperature inversions (Brown and Bradshaw 1994). Smoke from fires was noted in many early descriptions of forests in the Northern Rocky Mountains, including northern Idaho (see Mullan 1863; Plummer 1912). Burned area and smoke production were probably reduced during the fire exclusion era. However, recent increases in burned area and fire severity in dry forests of the Northern Rocky Mountains and the Pacific Northwest suggest that large fires and intense smoke production were postponed, rather than eliminated, by fire exclusion (Mutch 1994).

Fire management programs enable managers to exert some control over the timing and quantity of smoke emissions. Arno and Ottmar (1994) estimated that a prescribed burning program to improve forest health in the Blue Mountains of Oregon would produce about 37,500 tons of PM2.5 (particulate matter 2.5 microns or less in diameter) per year. Wildfires can release as much particulate matter in a few days, with no opportunity for managers to control smoke release or dispersion patterns. The 55,900 acre Sundance Fire in the Kaniksu National Forest produced 13,200 tons of PM2.5 during its 24 hour run on September 1 to 2, 1967 (Ward and Hardy 1991). The 1988 Canyon Creek fire in western Montana released more than 32,000 tons of PM2.5 in just 2 days (Ward and others 1994). During the summer of 1910, fires in Idaho and Montana produced more than 1 billion tons of total particulate matter (Ward and Hardy 1991).

Emissions from management-ignited fires are controlled by decreasing fuel consumption and by maximizing dispersal rates. Techniques include removing large fuels, yarding unmerchantable material, and selecting weather, fuel moisture conditions, and firing techniques to minimize smoldering and maximize dispersal (Peterson 1990; Ward and others 1988). Where fuels are piled for burning, emissions can be reduced by minimizing the dirt in piles (Peterson 1990). High-intensity burns produce lower proportions of small particulates and carbon monoxide than do fires with considerable smoldering combustion (Einfeld and others 1991). Very rapid ignition of prescribed fires (mass ignition) can reduce smoke emissions by as much as 23 percent because much of the heat produced is dispersed to the atmosphere instead of drying and preheating large woody material and duff (Hall 1991; Sandberg 1983).

Emission factors (the proportion of fuel consumption that is released in smoke) from flaming and smoldering combustion have been described for various regions of the United States, including the Rocky Mountains (Ward and others 1988). These factors have been adopted and published by the U.S. Environmental Protection Agency (1991). Some emission factors developed from tests in the Pacific Northwest (Ward and others 1989) are applicable to fuels in northern Idaho. Ward and Hardy (1991) suggested that knowledge of the intensity and efficiency of a fire, expressed as combustion efficiency, can be used to predict a fire-specific emission factor. Emission factors for carbon monoxide, methane, PM2.5, and total particulate matter all decrease as combustion efficiency increases (Hardy and others 1992; Ward and Hardy 1991).

Prescribed natural fire offers fewer opportunities than management-ignited fire for controlling emissions and dispersal rates. Current prescribed natural fire programs do not produce as much smoke as did presettlement fire regimes, mainly because they burn less area per year. In the Selway-Bitterroot Wilderness, Brown and Bradshaw (1994) estimated that poor visibility because of smoke occurred 33 percent more often during presettlement times than in recent times. Smoke emission rates, however, were higher in recent times because of increased fuel loadings and more stand replacement fire. Programs that use management-ignited fire to modify fuels, especially in dry forests, may be useful for reducing emissions from prescribed natural fire.

Increased use of prescribed fire to control the long-term impact of smoke from wildfire is likely to be acceptable to the public only with careful attention to air quality regulations, involvement of regulatory agencies, continued research, and public education (Arno and Ottmar 1994). The challenge, described by Acheson and Hardy (1995), is "to protect human health from undue smoke impacts while protecting the long term health of ecosystems dependent on fire."

Predicting Succession Quantitatively

In this report, we describe postfire stand development qualitatively, using the successional pathway concept described by Kessell and Potter (1980). These qualitative pathways provide a conceptual guide for

applying quantitative models of succession and stand development. Two such models are available: FIRESUM (FIRE SUccession Model), written specifically to predict fire-related succession; and the Forest Vegetation Simulator (Prognosis Model), a multipurpose model of forest development over time.

FIRESUM is an ecosystem process model that predicts fire-related succession in coniferous forests of the inland portion of the Western United States (Keane and others 1989). It can be used to evaluate the cumulative effects of different prescribed burning schedules on tree composition and structure, fuel loads, duff depths, and other stand characteristics at varying fire frequencies. Wildlife habitat potential can also be evaluated under different fire regimes. The current version of FIRESUM predicts succession for the following tree species: alpine larch, Douglas-fir, Engelmann spruce, grand fir, lodgepole pine, ponderosa pine, subalpine fir, western larch, and whitebark pine. Parameters can be adjusted to account for succession with western redcedar, western hemlock, western white pine, and mountain hemlock (Keane 1992). The model has been used to describe succession in Fire Groups Two (Keane and others 1990a) and Six (Keane and others 1990b).

To run FIRESUM, the user provides data describing a particular site and the structure and composition of the current stand. In addition, the user specifies the fire frequency to be simulated in the model, and the wind and fuel moisture conditions to be used in calculating fire behavior and fire effects. For each year simulated, the model estimates tree density and basal area by species, and fuel loading and duff depth. It incorporates fire behavior and effects for each fire year. The effects of mountain pine beetle and white pine blister rust are included.

The Prognosis Model and its extensions predict changes in stand structure and composition over time (Wykoff 1986; Wykoff and others 1982). Extensions to the model incorporate estimates of regeneration (Ferguson and Crookston 1991), changes in shrub cover and vertical stand structure over time (Moeur 1985), and effects of the following forest pests and diseases: Douglas-fir tussock moth (*Orygia pseudotsugata*) (Monserud and Crookston 1982), dwarf mistletoe (Hawksworth and others 1992), mountain pine beetle (Crookston and others 1978), western spruce budworm (Crookston and others 1990; Kemp and others 1989; Sheehan and others 1989), and various root diseases (Stage and others 1990). An extension modeling the effects of white pine blister rust is also in preparation (McDonald 1993). The Prognosis Model currently includes fire as a component of site preparation. An extension modeling fuel accumulation from tree mortality, branch fall, and litter fall is also being prepared (Reinhardt and Ryan 1995). Based on fuel calculations, this extension will model fireline intensity, fire-caused tree mortality, fuel consumption, and smoke production.

The Prognosis Model can be used to estimate long-term effects of different fire regimes through the Parallel Processing Extension in conjunction with the Event Monitor (Crookston 1990). Crookston and Stage (1991) demonstrated such an application. Tree removal and site preparation treatments were entered to describe various fire regimes. Fuel biomass varied with fire frequency, and stand composition varied with fire intensity. Use of the Prognosis Model in this manner can predict changes within many stands, up to 1,000, over a period of about 400 years. Therefore, this system could be used to model effects of different fire regimes at the landscape level.

Fire Management at the Landscape Level

This report describes fire regimes and fire management mainly at the stand level, but fire management is a landscape-level issue. In presettlement times, the distribution of cover types and structural stages over the landscape was strongly influenced by fire. Similar distributions may be useful for meeting future management goals, including the preservation of forest health and biodiversity (Groves and Unsworth 1993; Hejl 1994; Morgan and others 1994a).

Habitat type and fire group provide a useful framework for classifying fire regimes, although they do not account for nearly all of the variation that occurs in fire size, timing, and severity. In general, presettlement fires were more frequent and less severe in dry, low-elevation habitat types (Fire Groups One and Two) than in either higher elevation types (Groups Three through Six) or more moist types (Groups Seven through Nine). Nevertheless, variation from one study area to another within fire groups was great (fig. 9). Within Fire Group Eight, for instance, average intervals between severe presettlement fires range from 48 years (on shrubfields in the Cook Mountain area, Clearwater National Forest) (Barrett 1982) to more than 250 years (North Fork Clearwater River basin) (Barrett 1993). Furthermore, many studies show great variation in fire return intervals and fire severity patterns within study areas (see descriptions of fire regimes in individual fire groups, and Arno and others 1993). Variation has been attributed to effects of topography, elevation, fire regimes in neighboring stands, and the interactions of topography with climatic patterns (Green 1994; Steele and others 1986). Variation was at least as important as average trends in shaping the landscapes of presettlement times. Ecological process modeling (Keane and others 1990a, 1990b) indicates that vegetation and fuels would be different from presettlement patterns if fire return intervals were regular, without variation.

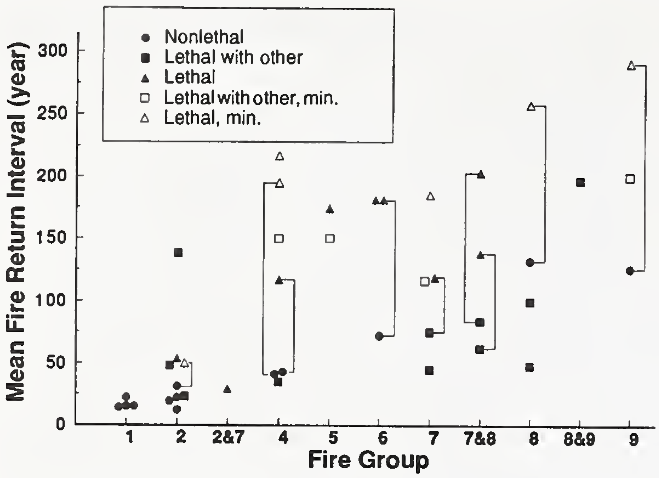

Figure 9—Estimated mean fire intervals from fire history studies in northern Idaho (locations shown on map, figure 1). Circles indicate nonlethal severity; triangles indicate lethal severity; squares indicate a mixture of severities. Open symbols indicate values presented as minima or including some open-ended fire return intervals. Brackets connect means reported for different levels of fire severity within a single study area. Means are listed in tables 17, 20, 23, 26, 28, 31, 37, and 40.

Spatial variation makes descriptors of historic fire regimes strongly related to the scale of measurement; thus, fire regime descriptors must be selected for their usefulness in answering specific ecological or management questions at a particular scale (Zack and Morgan 1994b). For example, a slope that is severely burned may show limited resprouting of herbs and shrubs because of heat penetration into the soil. A survey of the entire burn, however, would probably show sprouting species well represented in areas less severely burned. A survey that included unburned with burned areas in the ecosystem would show even greater variety in species composition and stand structures. Such broad-scale measurements are not very informative concerning specific stands, but they aid in understanding the occurrence and extent of various cover types and the spatial relationships between them. Fire history indicators useful at the landscape level include estimates of historic fire sizes and the intervals between "large" fires. Although very difficult to determine, several rough estimates are available from studies in northern Idaho (table 11). They indicate that "large" fires (defined for the particular study area) have occurred at average intervals of about 20 to 40 years.

To implement fire management at a landscape level, managers need to use fire ecology information and work together in new ways. Mutch and others (1993) described the dialogue that will be needed to increase prescribed fire use and restore ecosystem health in the Blue Mountains of Oregon:

> Many people within the National Forest System are trying to implement a philosophy of sustaining healthy ecosystems, but specialists remain committed to independent, functional goals....
>
> ...New requirements in terms of internal interdisciplinary cooperation, public involvement and understanding, risk taking, funding, and interagency communications will challenge everyone's ability to perform effectively. Progress will depend on whether leadership is focused on the goal of

Table 11—Large-scale descriptions of presettlement fire regimes in northern Idaho.

Location	Study area	Fire groups included	Area mean fire Interval[a]	"Major" fire definition
	Acres		*Years*	
Coeur d'Alene River Basin, Coeur d'Alene National Forest[b]	570,000	7,8,9	19	≥ 5% of area, or ≥ 28,000 acre
N. Fork Clearwater R. basin, Clearwater National Forest[c]	5,000	7,8,9	28	Stand replacing
Cook Mtn. shrubfields, Clearwater National Forest[d]	83,000	2,4,5,7,8	25	≥ 10,000 acre
White Sand Area, Clearwater National Forest[c]	8,000	4,5	40	Stand replacing
S. Fork Clearwater R., Nez Perce National Forest[c]	10,000	1,2,7	8	Mixed severity
Salmon R. (R. of No Return), southern edge, Nez Perce National Forest[e]				
- Colson Creek	3,000	1,2	21	≥ 1,000 acre
- Chamberlain/Disappointment	4,000	1,2	41	≥ 1,000 acre

[a]"Area mean fire interval" is the average time between "large" or "major" fires (defined for a particular study) within a study area (Barrett 1993).
[b]Zack and Morgan (1994b).
[c]Barrett (1993).
[d]Barrett (1982).
[e]Barrett (1984).

sustaining forest health. Evaluating and rewarding line officers on their contributions towards sustaining healthy ecosystems might provide the necessary incentives to promoting commitment.

Prescribed burning on a landscape scale has several practical advantages, including greater likelihood of obtaining a complex mosaic of vegetation, less chance of degrading low-productivity sites, and potentially lower costs.

Successional Communities Occurring in More Than One Fire Group

Two plant communities are common in northern Idaho forest habitat types, but are not limited to a specific fire group: persistent seral shrubfields and seral lodgepole pine forests. General characteristics of these two community types are described here, and information that applies to specific fire groups is covered within the appropriate groups.

Persistent Seral Shrubfields

Large expanses of shrub-dominated slopes, where tree regeneration is sparse or lacking, characterize many areas in northern Idaho. These persistent shrubfields occur under a variety of environmental conditions, although they are especially prevalent on south- and west-facing slopes that have burned repeatedly (Anonymous 1931; Wellner 1970a). Scarcity of indicator tree species and downed woody material makes determination of habitat type difficult, but shrubfields apparently occur widely in Fire Groups Two, Seven, and Eight, and on isolated sites in Fire Groups Four and Five (Barrett 1982; Zack 1993). General characteristics of persistent shubfields, not unique to a particular fire group, are summarized here.

Reasons for Persistence of Seral Shrublands—Dry weather patterns following canopy removal and repeated severe fires ("reburns"), especially on dry sites, are likely to produce persistent shrubfields (Marshall 1927; Wellner 1970a). Barrett (1982) defined a reburn as a fire that burns in heavy downed woody fuel that resulted from tree mortality in a previous fire, occurring when tree regeneration is in the seedling or sapling stage. These conditions are common when fires occur within 30 years of each other; numerous reburns occurred in northern Idaho after the severe fires of 1910 (Pyne 1982). Approximately 25 percent of the area burned in the Clearwater National Forest between 1860 and 1931 was in reburns, followed by negligible postfire tree regeneration (Anonymous 1931).

Lack of seed inhibits tree regeneration on reburns, but it is not the only cause, since both planting and natural regeneration have failed on these sites (Barrett 1982). Increased soil temperatures and increased moisture stress can result from overstory removal and reduction of the soil's organic matter. Erosion after severe burns, especially on south-facing slopes, also impedes tree regeneration (Larsen 1925; Wellner 1970b). Loss of the fertile ash cap layer is particularly damaging to sites in northern Idaho. Barrett (1982) suggested two additional factors contributing to the persistence of seral shrubfields: (1) reburns reduce soil wood so that nitrogen fixation, micorrhizae inoculum, and microsites for tree establishment are limited; and (2) shrubfield recycling may elevate soil pH beyond levels conducive to conifer establishment.

Fuels—The fuels in persistent shrubfields differ in quantity and spatial distribution from those on forested sites. Repeated severe fires have removed most large woody material. Herbaceous fuels are also relatively light; shrubfields in the Avery District of the St. Joe National Forest had only 10 percent canopy cover of herbs, comprising an average biomass of 0.4 ton per acre (data on file at Intermountain Fire Sciences Laboratory, Missoula, MT). Litter was also light, but duff loading averaged 12.1 tons per acre. Standing shrubs comprised most of the biomass (table 12). Shrubs averaged 6 ft tall, with nearly 70 percent canopy coverage. Total shrub fuel loading averaged 19.7 tons per acre, 11 percent of which was dead. The shrubfields were dominated by *Acer glabrum*, *Amelanchier alnifolia*, *Ceanothus* species, *Salix* species, and *Vaccinium globulare* (table 13). *Pachistima myrsinites* often occurs in a middle shrub layer under dense tall shrubs (Hann 1986).

Table 12—Fuel loads (tons/acre) on two shrubfields near Avery Ranger Station, St. Joe National Forest. (Data are on file at Intermountain Fire Sciences Laboratory, Missoula, MT.)

Site No.	Duff depth,	Duff load,	Dead and downed load by size class (inches) 0-¼	¼-1	1-3	3+ sound	3+ rotten	Total dead and downed	Total shrub load
	Inches	*Tons per acre*							
1	0.8	14.4	0.3	1.8	1.2	0.0	0.0	3.3	16.0
2	0.5	9.8	0.2	0.9	1.0	0.0	0.0	2.1	23.4

Table 13—Average fuel loads (tons/acre) for individual species on two shrubfields near Avery Ranger Station, St. Joe National Forest. (Data are on file at Intermountain Fire Sciences Laboratory, Missoula, MT.)

	Shrub load (live + dead) by stem diameter class (inches)			
Shrub species	0-1	1-3	3+	Total
Acer glabrum	0.0	0.4	2.3	2.7
Amelanchier alnifolia	0.1	2.4	1.5	4.0
Ceanothus species	0.0	1.4	1.3	2.7
Physocarpus malvaceus	0.1	0.4	0.0	0.5
Prunus virginiana	0.0	0.1	0.3	0.4
Rubus parviflorus	0.1	0.0	0.0	0.1
Salix species	0.0	0.1	2.7	2.8
Spiraea betulifolia	0.2	0.0	0.0	0.2
Vaccinium globulare	0.4	3.6	0.0	4.0
Total for these species[a]	0.9	8.4	8.1	17.4

[a]Other species on the sites included *Mahonia repens, Lonicera utahensis, Rosa* species, *Symphoricarpos albus,* and *Vaccinium scoparium.*

Persistent shrubfields can burn in nearly any season. Snow generally disappears early in the spring on south- and west-facing slopes. If surface fuels are continuous and dry, spring fires spread readily. In the summer, shrubfields are often hot and very dry, conditions exacerbated where nighttime temperature inversions occur. (See "Role of Fire" in Fire Group Eight for discussion of thermal belt conditions in northern Idaho.) Shrub foliage is not particularly flammable when green, but hot, dry winds during drought conditions can drive severe fires through the shrub layer. Shrubfields are often prescribed burned in the fall, when the slopes are warmed and dried by low-angle sunlight and litter from the current year's foliage is deep.

Role of Fire—Severe reburns are the main cause of persistent seral shrubfields. The Avery shrubfields in the St. Joe National Forest have burned three times in this century (Zack 1993); two of the fires were very severe. In the south- and west-facing shrubfields surrounding Cook Mountain, Clearwater National Forest, Barrett (1982) documented fire return intervals averaging about 31 years. Most fires were either surface burns lethal to all but a few trees per acre, or crown fires that burned over hundreds of acres. Fires larger than 10,000 acres burned through the area about every 25 years (table 11). In recent times, fire exclusion and fuel management may have reduced reburning and thus limited the expansion of seral shrubfields (Wellner 1970a).

After shrubfields burn, shrubs regenerate readily from seed and underground parts. Larsen (1925) described succession on severe double burns in the Coeur d'Alene National Forest: At first, *Salix* species establish from seed, along with *Epilobium angustifolium*, *Solidago* species, and *Cirsium* species. After about 10 years, most of the herbaceous species decline as dense shrub cover develops: *Ceanothus* species, *Acer glabrum*, *Amelanchier alnifolia*, *Vaccinium globulare*, *Holodiscus discolor*, *Physocarpus malvaceus*, *Rubus parviflorus*, *Symphoricarpos albus*, *Sambucus racemosa*, and *Prunus* species. Most upper south-facing slopes and knolls are covered by almost-pure stands of *Ceanothus velutinus*. Mueggler (1965) and Drew (1967) listed the following additional species as common on burned clearcuts (not necessarily reburned) in northern Idaho: *Pachistima myrsinites*, *Alnus sinuata*, and *Spiraea betulifolia*.

Trees regenerate slowly, if at all, in persistent shrubfields. If soil organic matter is depleted, decades or centuries may be needed to restore it. The Avery shrubfields had average tree densities ranging from less than 10 to 17 per acre, with less than 1 percent cover (Hann 1986). Some shrubfields in the Cook Mountain study area have been in existence for 200 years or more; large expanses of south-facing slopes contained no tree regeneration (Barrett 1982). On the south-facing sites where some regeneration was occurring, canopy cover averaged less than 30 percent; Douglas-fir, grand fir, and lodgepole pine were the most frequent species. Shiplett and Neuenschwander (1994) suggested that persistent shrubfields in northern Idaho can regenerate very slowly to mixed stands containing western white pine, Douglas-fir, ponderosa pine, and grand fir. Lodgepole pine may also occur, but lodgepole pine and western larch do not regenerate well under the shade of, and in competition with, dense shrubs (Hann 1986).

Fire Management Considerations—Elk and deer use shrubfields for winter range, although some tree cover may be required, especially by white-tailed deer (Mueggler 1965; Yeo and Peek 1994). Fire can be used to maintain shrub productivity on old shrubfields and to encourage shrub dominance after timber harvesting. Leege (1979) described a program of prescribed burning every 10 to 15 years to maintain forage for northern Idaho elk herds. Burning at 5 year intervals decreases the vigor of most shrubs.

Many efforts at reforesting persistent shrubfields have failed, so Barrett (1982) recommended site-by-site analysis of fire history and soils before planning reforestation. Tree establishment can be encouraged by: (1) excluding wildfire, (2) using site preparation methods that do not stimulate grassy or shrub species, and (3) planting or seeding hardy pioneer species under the shade of killed shrubs. Succession in the absence of fire gradually reduces preferred pocket gopher habitat, thus improving conditions for regeneration in areas with high gopher populations. Considering the difficulty of establishing trees on reburned shrubfields, it seems advisable to be conservative in using fire to produce or maintain them.

Seral Lodgepole Pine

In geographic areas outside northern Idaho, seral lodgepole pine occurs mainly in dry, lower subalpine habitat types (for example, central Idaho, as described in Crane and Fischer 1986; western Montana, as described in Fischer and Bradley 1987). In northern Idaho, however, lodgepole pine can dominate early succession under a wide range of conditions—from low-elevation flood plains and frost pockets to both dry and moist subalpine sites. Seral lodgepole pine occurs in more than one-third of northern Idaho's habitat types (Cooper and others 1991). In this section, we describe general characteristics of forests dominated by seral lodgepole pine. In the description of each fire group where seral lodgepole pine can be dominant (Two, Four, Five, Seven, and Eight), we describe characteristics of seral lodgepole pine stands unique to that group.

Reasons for Dominance by Seral Lodgepole Pine—Lodgepole pine tends to dominate in frost pockets and on cold, dry sites. It also dominates many sites with soils that are saturated in the spring but very dry later in the summer. Where these conditions are extreme, lodgepole is persistent or climax (Fire Group Three). On moderate sites, lodgepole pine dominance after disturbance depends on the presence of abundant seed, which is partly a function of stand history. Fire-free intervals less than the life span of lodgepole pine favor lodgepole dominance. Fire-free intervals greater than the life span of lodgepole pine, plus some time to account for the loss of standing dead trees bearing closed cones, favor dominance by other species.

Fuels—The amount of fuel in seral lodgepole pine stands varies (Brown and See 1981). Examples of fuel loadings are given for seral lodgepole pine stands in Fire Groups Four (Stands 4A, 4D, and 4E in table 22), Six (Stand 6B, table 27), Seven (Stand 7G, table 30), and Eight (Stand 8B, table 35). Changes in fuel loadings over time are affected by decomposition of material killed but not consumed by the previous fire, the fall and decay of snags (fig. 7), stand development, and effects of insects and diseases.

Fire hazard in lodgepole pine stands is extremely variable, as illustrated in figure 10 (Brown 1975). Curve A of that figure corresponds to what Muraro (1971) described as the typical pattern of fire hazard in lodgepole pine. Young, especially dense stands have high fire potential because fire itself can generate heavy surface fuels. Heavy loadings of woody fuels increase the potential for severe fire behavior, although they may not directly affect ignition probability or fire spread (Anonymous 1931). Moderately dense immature and mature stands have the lowest fire hazard. As tree growth rates decline, surface fuels and fuel ladders increase because of increased downfall and establishment of shade-tolerant conifers; potential fire intensity also increases. Curve C depicts a different, not uncommon pattern of potential fire intensity in lodgepole pine stands, where surface fuels remain sparse throughout stand development until growth rates decline. Lodgepole pine stands can also vary between Curves A and C during younger growth periods and then develop high fire potential at maturity (Curve B).

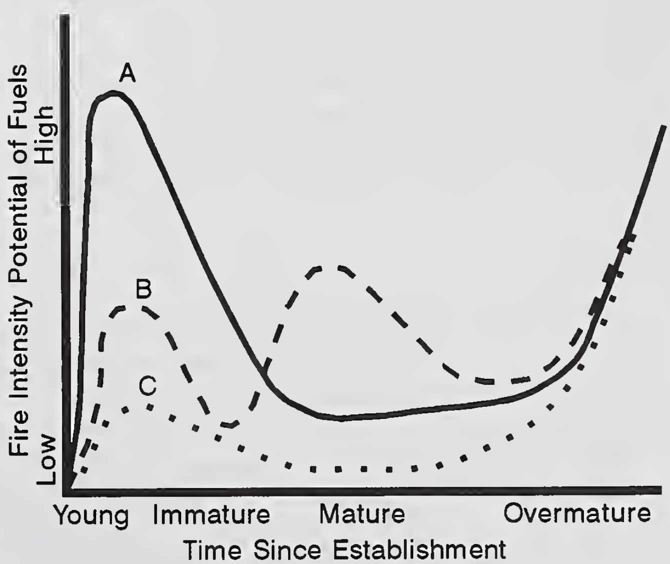

Figure 10—Fuel cycles and fire intensity potential in lodgepole pine (Brown 1975). See text for description of curves A, B, and C.

Insect infestations and disease alter the quantity and spatial distribution of fuels in lodgepole pine stands. Mountain pine beetle irruptions cause very high mortality in mature stands of seral lodgepole pine. Amman and Cole (1983) indicated that most lodgepole stands are susceptible about 80 years after establishment. In western Canada, Safranyik and others (1975) found that trees become susceptible when they exceeded 10 inches d.b.h. Heavy litter and fine fuels that result from pine beetle mortality increase the potential for high-intensity fire. Increased loads of large fuels increase the potential for severe, long-duration fire (Omi and Kalabokidis 1991). Armour (1982) described dead and downed woody fuels in beetle-killed lodgepole pine stands in the PSME/CARU habitat type, western Montana. Woody fuels in most size classes reached maximum quantities either 30 or 80 years after pine beetle irruption and were lower in older stands. Accumulation of fuels in the PIEN/CLUN habitat type (similar to the ABLA/CLUN habitat type of northern Idaho) was rapid during the first 30 years after pine beetle irruption and continued, but at a slower rate, during the next 50 years.

Role of Fire—Fire behavior in lodgepole pine tends toward either of two extremes. Fires either smolder and creep slowly on the soil surface, consuming mainly litter and duff, or they burn in severe, stand-replacing events. Cool, moist conditions usually prevail under a dense closed canopy, so fires that start in lodgepole pine stands often remain on the ground, smoldering for days or even weeks in the sparse undergrowth before going out (Lotan and others 1985). Mortality of lodgepole pine is often low after low-severity fires, producing widely spaced or patchy stands. If low-severity fires burn in dry duff, mineral soil will be exposed, enhancing regeneration.

The likelihood of crown fire in lodgepole pine stands is governed by the amount of heat released from surface fuels, the height of tree crowns above surface fuels, and weather conditions. Severe fires are most likely to occur where there are heavy concentrations of dead or mixed dead and live fuels. If individual trees or groups of trees torch, fire can continue to travel through the crowns aided by steep slopes and high winds. Although stand-replacing fires are less frequent than low-severity burns, they can burn very large areas in a short time.

After stand-replacing fire, lodgepole pine regenerates readily on moist sites (Lotan and others 1985). Stocking is less on dry sites because of moisture stress. The density and rate of regeneration depend to some extent on the prevalence of serotinous (closed) cones in the original stand (Lotan 1975). (See "Lodgepole Pine" in "Relationships of Major Tree Species to Fire.") Regeneration from serotinous cones is usually rapid and dense. Seed from open-coned trees establishes less dense stands that are somewhat uneven-age. Crown fires usually cause the maximum release of stored seed, but surface fires with considerable torching can produce similar results.

Lodgepole pine can become established in nearly pure stands, or other species may become established at the same time, but be suppressed, under the fast-growing pines. In either case, lodgepole pine regeneration dominates. On productive sites in northern Idaho, dense lodgepole regeneration may continue very slow growth instead of stagnating (Bosworth 1994). However, it is short-lived; lodgepole pine dominates few stands in northern Idaho after 120 years of succession (Cooper and others 1991).

Mountain pine beetle is nearly ubiquitous in lodgepole pine forests. The likelihood of severe pine beetle infestation varies with habitat type; in southeastern Idaho and northwestern Wyoming, the proportion of stands infested was greater in moist than dry habitat types (table 14). According to Amman (1977), the role played by mountain pine beetle in seral lodgepole pine is to periodically remove the large dominant pines. After an infestation subsides, growth rates increase in residual lodgepole pine and other species present. When the pines are of adequate size and phloem thickness to support pine beetle populations again, another infestation occurs. This cycle is repeated at

Table 14—Mountain pine beetle infestation of lodgepole pine stands in southeastern Idaho and northwestern Wyoming (Roe and Amman 1970).

Habitat type	Northern Idaho fire group	Percent of stands infested
Pseudotsuga menziesia/Calamagrostis rubescens	2	64
Abies lasiocarpa/Vaccinium scoparium	3	44
Abies lasiocarpa/Pachistima myrsinites[a]	4,5	92

[a]This habitat type, from Daubenmire and Daubenmire (1968), corresponds to the northern Idaho habitat types ABLA/CLUN (all phases) and ABLA/STAM-LICA from Cooper and others (1991).

20 to 40 year intervals, depending on tree growth rates, until lodgepole pine is eliminated. Thus the continued presence of both lodgepole pine and mountain pine beetle in seral lodgepole pine depends on fire. Large accumulations of dead material caused by periodic beetle infestations increase the severity of fire behavior when these stands burn (Brown 1975).

Fire Management Considerations—Stands dominated by seral lodgepole pine historically followed a dramatic life cycle: stand-replacing fire, lodgepole pine reproduction and growth, disease or insect mortality, then stand-replacing fire. Barrett and others (1991) commented on fire exclusion in landscapes dominated by seral lodgepole pine in Glacier National Park, MT: "If fire [exclusion] enhances the extent and severity of pine beetle epidemics, then more extensive fires would be expected in the resultant fuels.... Fire history reveals the inherent irony and futility of this approach, and consequently the need for new management strategies." Even when fires in heavy fuels are not severe, they can burn for a long time, with an increased potential to initiate stand-replacing fire if low humidity and high winds occur (Brown and See 1981).

Mortality from mountain pine beetle irruptions increases the challenge of protecting lodgepole pine forests during periods of severe fire weather, since fire suppression in heavy large fuels is arduous, expensive, and dangerous. Opportunities for management-ignited fire are very limited because fire spread cannot easily be sustained during times when burning conditions are usually considered safe. Fuel reduction programs near wilderness boundaries could be used to increase management options within wilderness areas and protect resources outside wilderness. Omi and Kalabokidis (1991) recommended fuel removal or prescribed burning to decrease fire hazard in mature stands where mountain pine beetle infestations have occurred. Cole (1978) suggested that management using both natural and artificial ignitions can be used to "create a mosaic of regenerated stands within extensive areas of timber." Guidelines have been developed to assist forest managers in integrating management of the mountain pine beetle with other resource considerations (McGregor and Cole 1985).

The primary use of prescribed fire in lodgepole pine is for hazard reduction and site preparation after tree harvesting. Broadcast burning and pile and windrow burning have been the methods most often used. Slash disposal of any kind aids big game movement through stands. Broadcast burning usually increases forage for big game. To minimize the potential extent of stand-replacing fires in ecosystems with considerable seral lodgepole pine, harvest plans can be designed to enhance age-class mosaics. Lotan and Perry (1983) summarized the considerations that determine the appropriate use of fire for site preparation and regeneration of lodgepole pine forests in southwestern Montana. Their recommendations may be useful in management of seral lodgepole pine on dry sites in northern Idaho.

Prescribed fire has been suggested as a management tool for controlling dwarf mistletoe in lodgepole pine in Colorado (Zimmerman and others 1990). Low-severity burns, however, leave mistletoe-infested trees that infect regeneration (Alexander and Hawksworth 1975).

Dense lodgepole pine regeneration in the Northern Rocky Mountains can stagnate in the pole size class (table 15), but many dense stands in northern Idaho continue to develop with slow growth (Bosworth 1994). Where stagnation occurs, fire can be used to regenerate lodgepole pine. Schmidt (1987) summarized fire management considerations for such a program: Fire intensity must be regulated carefully to reduce, but not eliminate, seed supply. Insect and disease problems are often reduced, and forage is usually increased. Poorly managed burning can perpetuate overstocking or remove all seed, requiring later planting or seeding.

Grasses and forbs are often seeded after wildfire to decrease erosion potential; grasses compete severely with lodgepole pine seedlings, and use of non-native species causes long-term changes in community composition (Lyon 1984). Where exotic grasses were seeded after the Sleeping Child Burn (Bitterroot National Forest, MT), grass cover averaging 29 percent was associated with seedling attrition of 21 to 29 percent; in contrast, grass cover of less than 1 percent was associated with seedling attrition of only 4 to 5 percent.

Fire Group Zero: Miscellaneous Special Habitats

Fire Group Zero is a group of habitats that neither form a widespread vegetative zone nor fit into the habitat type classification for northern Idaho.

Scree Slopes

"Scree slopes" refer to slopes covered with loose rock fragments, usually lying near the maximum possible angle of repose so that any disturbance causes minor rock slides down the face of the slope. Scree slopes may support scattered trees with sparse undergrowth. Quaking aspen stands are characteristic of moist scree near seeps and on toe-slopes. Scree communities are regarded as special environments where the vegetation is in an uneasy equilibrium with the unstable substrate.

Discontinuous fuels often make scree slopes unburnable. Individual trees or islands of vegetation can ignite, but fire spread is limited. Severe, wind-driven fire can kill the vegetation in a scree community, but this rarely happens. Due to the harsh

Table 15—Relationships among stand age, stocking, tree development, and typical yield in natural stands of lodgepole pine, summarized for medium sites in Montana and Idaho (site index 75 feet at base age 100 years) (Lotan and Critchfield 1990)[a].

Age	Trees per acre	Average height of dominants	Average stand diameter	Total cubic volume	Merchantable volume
Years		*Feet*	*Inches*	------ *Ft³/acre*	------
20	500	18	3.4	230	—
	8,000	10	1.6	400	—
50	479	41	6.5	2,070	1,860
	6,150	30	2.7	2,370	—
80	418	59	8.1	4,080	3,800
	3,034	48	3.6	4,000	—
110	344	73	9.3	5,510	5,190
	1,861	62	4.5	5,100	3,900
140	275	83	10.5	6,410	6,090
	1,243	73	5.5	5,950	4,300

[a]Compiled from unpublished yield tables from D. M. Cole, U.S. Department of Agriculture, Forest Service, Intermountain Research Station, Bozeman, MT. Cubic volumes are from trees 4.5 inches d.b.h. to a 3 inch top.

environment, reforestation following fire can take a very long time.

Forested Rock Communities

Forested rock communities occur on very steep canyon walls or mountainsides, with occasional clumps of trees clinging to ledges and crevices. Forested rock is especially prominent along canyons and in rugged upper subalpine areas near timberline. These sites are similar to scree slopes, but the substrate is solid. Climax species frequently become established in pockets of soil and in rock crevices.

Surface fires do not burn well in forested rock communities because of the vertical and horizontal discontinuity of ground fuels. The probability of crown fires depends on the density and arrangement of trees on the rock face. In some cases, the islands of vegetation are so widely scattered that they are almost immune to wildfire. Where foliage is continuous from the base to the top of a cliff, however, each tree forms a ladder into the lower branches of the next higher tree. Such fuel arrays occasionally support crown fires over ground that would not support less severe surface fire.

Revegetation of rocky sites proceeds at a rate characteristic of the site and depends on the severity of the fire, the age and depth of the soil on ledges and in pockets of rock, the degree of erosion, and the availability of seed.

Wet Meadows

A wet meadow is an opening in the forest characterized by herbaceous vegetation and abundant moisture. Subirrigation is common during at least part of the growing season. Grass-dominated meadows can burn early in the spring following snowmelt and prior to greenup. Most meadows are too wet to burn during midsummer. During late summer and early fall, however, and during drought years, they become dry enough to burn.

Streamside meadows become drier during the course of succession. Accumulation of organic material and trapped sediments from flowing water, combined with deepening of the streambed and lowering of the water table, gradually convert them to grassland. On some sites, such meadows intergrade with grasslands historically maintained by fire.

Deciduous Riparian Communities

Deciduous riparian communities occur on sites adjacent to seasonal or perennial free-flowing streams or open bodies of water; they are dominated by deciduous trees, shrubs, and herbaceous vegetation. Deciduous riparian communities are often found in a narrow strip along drainage bottoms or between streambeds and upland forest vegetation. Overstory dominants include black cottonwood, quaking aspen, *Salix*, *Acer*, and *Alnus* species. Some upland conifers, particularly Engelmann spruce, intermingle with deciduous species on riparian sites. The understory is lush and includes a diverse assemblage of forb and grassy species (Hansen and others 1995).

Although riparian communities are productive and frequently have large amounts of live and dead woody fuels, moist conditions and rapid decomposition of leaf litter generally inhibit fire spread. The vegetation in

riparian zones often remains unburned, even when severe fires occur in adjacent upland areas; thus they often moderate the effects of stand-replacing fire on stream corridors (Snyder and others 1975). Wind-driven fires originating in surrounding forests, however, may carry into riparian communities, especially during drought. Such fires topkill most woody vegetation and kill roots of some species. In areas where fire exclusion has increased potential fire severity on upland sites, riparian sites may be more likely to burn than they were prior to Euro-American settlement. Heavy postfire rainfall magnifies the impact of severe fire on the site itself and on riparian areas downstream.

Revegetation of burned areas occurs soon after fire because of abundant moisture. All of the dominant woody species are able to resprout after top-kill. Shrubby species dominate for several years. Fast-spreading fires produce more *Salix* sprouts than slow fires, which can damage root crowns. If fire is planned to rejuvenate riparian *Salix*, elimination of livestock use in the year before burning is essential (Hansen and others1995). Cottonwood, *Salix*, *Alnus*, and *Acer* species all have airborne seeds that can colonize burned areas from considerable distances.

Alder Glades

Permanent alder communities in northern Idaho, dominated by *Alnus sinuata* or *Alnus incana*, have been described by Daubenmire and Daubenmire (1968) and Cooper and others (1991). Alder glades occur within most of the moderate and moist habitat types of northern Idaho. In the Grand Fir Mosaic Ecosystem (Ferguson 1991), alder glades intermix with stands of shade-tolerant conifers and patches dominated by *Pteridium aquilinum* and *Rudbeckia occidentalis*, especially where disturbed. (See Fire Group Seven.)

Alder glades form on seepage sites, either as narrow stringers or as isolated patches taking the shape of the water source. Their understories contain species characteristic of both mesic and wet sites, including ferns, *Aconitum columbianum*, *Montia* species, *Senecio triangularis*, and *Veratrum viride* (Daubenmire and Daubenmire 1968).

Because alder glades depend on the constant availability of water, they remain moist throughout the summer and do not burn readily. Their deciduous leaves are not shed until late fall, when conditions are usually too moist for fire spread. Alder glades could interrupt the spread of low-severity fires, but they are too small and narrow to influence the spread of severe, wind-driven fires. When burned, alders resprout vigorously from surviving root crowns and can also germinate from wind-dispersed seed.

Bracken Fern Glades

Bracken fern (*Pteridium aquilinum*) dominates openings as large as 15 acres in the Clearwater and Nez Perce National Forests. Bracken glades contain other moisture-loving herb species but very few woody plants. Lack of coarse charcoal in the soil indicates that some bracken glades have persisted for centuries (Ferguson 1991); other glades have become established following recent disturbance. An aggressive pioneer species, bracken invades disturbed sites rapidly and alters soil properties, making reforestation difficult (Ferguson and Boyd 1988).

Bracken produces several tons of flashy fuels per acre (McCulloch 1942), which burns readily when dry. A rough estimate of fuel loading can be obtained using the "narrow-leaved forb" class in Brown and Marsden's (1976) study of fine fuel quantities. To obtain an accurate appraisal of loading for a specific site, however, some clipping and weighing is necessary.

Although bracken fern's rhizomes are sensitive to heat, they are deep and well insulated by the soil, so the species sprouts vigorously after fire. Burning also enhances colonization by bracken because it reduces competing species temporarily, removes accumulated allelopathic substances, and creates conditions favorable for sporophyte establishment (Ferguson 1991). Bracken increases following fire are well documented (for example, Leege and Goldbolt 1985; Mueggler 1965; Stickney 1986). However, research in New Zealand indicated that midsummer fires reduced subsequent bracken vigor for 2 years (Preest and Cranswick 1978), apparently because starch reserves in the rhizomes were low at the time of burning.

Subalpine Parks

Treeless meadows and prairie fragments occur near the tops of many ridges and mountains in northern Idaho (Daubenmire 1943, 1980, 1981). Most of the prairie fragments occur on south-facing windward slopes and are dominated by *Festuca viridula*, *Festuca idahoensis*, and *Pseudoroegneria spicata*. These parks are surrounded by bands of shrubs and stunted trees. Tree growth on windward sites is apparently limited by moisture. Prevailing winds keep these slopes nearly snow-free during the winter; thin, coarse soils and climate limit moisture retention during the summer.

The role of fire in creating and maintaining subalpine parks is not well understood. The environment in which high subalpine forests exist is marginal for tree establishment and growth, so stand-replacing fire can create openings that persist for centuries (Agee 1993). Daubenmire (1981) found some subalpine firs within subalpine parks in northern Idaho, evidence that low-severity fires had not occurred despite the apparent

availability of fuels. He found no evidence that trees were invading these parks in the absence of fire.

In subalpine parks on lee slopes (usually north-facing), tree establishment is limited by accumulations of wind-borne snow that deform tree seedlings, shorten the growing season, and maintain cold, wet soil throughout most of the summer. The flora of these "snowpatches" contains *Luzula hitchcockii* and many plants characteristic of *Menziesia ferruginea* understories (Fire Group Five) (Daubenmire 1981). Fire is very infrequent in these moist mountain parks.

Fire Group One: Warm, Dry Douglas-fir and Ponderosa Pine Habitat Types

Pinus ponderosa/Agropyron spicatum h.t. (PIPO/AGSP), ponderosa pine/bluebunch wheatgrass
Pinus ponderosa/Festuca idahoensis h.t. (PIPO/FEID), ponderosa pine/Idaho fescue
Pinus ponderosa/Symphoricarpos albus h.t. (PIPO/SYAL), ponderosa pine/common snowberry
Pseudotsuga menziesii/Agropyron spicatum h.t. (PSME/AGSP), Douglas-fir/bluebunch wheatgrass
Pseudotsuga menziesii/Festuca idahoensis h.t. (PSME/FEID), Douglas-fir/Idaho fescue
Pseudotsuga menziesii/Spiraea betulifolia h.t. (PSME/SPBE), Douglas-fir/white spiraea
Pseudotsuga menziesii/Symphoricarpos albus h.t. (PSME/SYAL), Douglas-fir/common snowberry

Vegetation

Fire Group One consists of the warmest, driest forest habitat types found in northern Idaho (fig. 11, table 16). Sites in this fire group occur near lower timberline, mainly in the southern and western parts of northern Idaho. Tree growth and reproduction are hampered by a scarcity of soil moisture, especially where sites are on steep, south- or west-facing slopes. Mature stands are dominated by large, old ponderosa pine or Douglas-fir, with canopy cover often less than 30 percent and seldom reaching 50 percent (Cooper and others 1991; Froeming 1974). The occasional occurrence of a duff-consuming fire, followed by a good seed crop and then adequate moisture, produces tree regeneration episodically (Cooper and others 1991), but good seed crops are infrequent.

Grasses and low shrubs dominate the understory in Fire Group One. Shrubs often occur in the midst of grassy slopes as small patches or narrow stringers, maintained there by topographic or edaphic conditions that moderate the arid climate. Dominant grasses include *Festuca idahoensis*, *Pseudoroegneria spicata*, *Calamagrostis rubescens*, and *Carex geyeri*. The introduced species *Bromus tectorum* thrives on heavily grazed or disturbed sites. Important forbs include *Achillea millefolium*, *Arnica cordifolia*, and *Balsamorhiza sagittata*. Low shrubs include *Symphoricarpos albus*, *Spiraea betulifolia*, and *Mahonia repens*. Tall shrubs (*Amelanchier alnifolia*, *Ceanothus velutinus*, *Crataegus douglasii*, *Pachistima myrsinites*, *Physocarpus malvaceus*, *Rosa gymnocarpa*, and *Rosa woodsii*) occur in some stands (Cooper and others 1991; Merrill 1982; Steele and Geier-Hayes 1994). Where *Pteridium aquilinum* is widespread, it indicates past disturbance by fire or grazing.

Fuels

Fuel loads in Fire Group One are generally the lightest found in northern Idaho. Often, the most abundant surface fuel is cured grass; amounts vary with site conditions and growing season. Herbage production decreases with increasing forest canopy cover (Froeming 1974). Needle litter is an important component of surface fuels, with continuity, amount, and depth increasing as time since fire increases. Brown and Bradshaw (1994) described fuel models for stands in Fire Groups One and Two in the Selway-Bitterroot Wilderness. To represent the open ponderosa pine stands typical of presettlement times, they used the following loadings for surface fuels (tons per acre): litter, 0.6; duff, 2.3; herbs, 0.2; shrubs, 0.4; and tree regeneration, 0.2. The fuel models indicate that loadings of duff, shrubs, and tree regeneration were at least 50 percent less in presettlement stands than in modern-day stands.

Downed woody fuels consist of widely scattered, large trees (deadfalls) and concentrations of twigs, branchwood, and cones near the bases of individual trees. The amount of woody fuel less than 3 inches in diameter often averages less than 1 ton per acre and rarely exceeds 5 tons per acre. In the Selway-Bitterroot Wilderness, total downed woody fuels averaged 4.1 tons per acre in PSME/SYAL stands (Walker 1973). Heavy large fuels result from competition, fire, insects, disease, wind and snow damage, and harvesting. In central Oregon, ponderosa pine stands severely infested with dwarf mistletoe contained significantly heavier loadings of dead surface fuels in all size classes than did uninfested or mildly infested stands (Koonce 1981). Morgan and Shiplett (1989) found 22.1 tons per acre of woody debris in a harvested PIPO/FEID stand in southwestern Idaho.

Table 16 shows fuel loadings for three of the Fire Group One stands shown in figure 11. Stand 1B is relatively open. Canopy cover is greater in Stand 1C, where pole- and medium-size Douglas-fir predominate; these account for the heavier loading of fine woody material (1 inch and smaller). A few large branches and downed logs account for the heavy total woody fuel loading in Stand 1D.

Figure 11—Vegetation and fuels in Fire Group One. A. Stand 1A, open forest in PSME/AGSP habitat type on southwest-facing slope, Powell District, Clearwater National Forest. Medium and large trees are ponderosa pine, some with fire scars. Other trees are Douglas-fir less than 15 inches d.b.h. B. Stand 1B, open stand of medium and large ponderosa pine on south-facing slope just north of Salmon River, in Nez Perce National Forest. C. Stand 1C, east-facing slope dominated by pole- and medium-sized Douglas-fir with some medium-sized ponderosa pine. D. Stand 1D, steep, southeast-facing slope dominated by ponderosa pine in all size classes. Photos B-D are from Salmon R. District, Nez Perce National Forest, taken by Jim Mital.

Table 16—Stand characteristics and fuel loadings in some Fire Group One stands. Loadings are in tons/acre. (Data were provided by Jim Mital and are on file at Intermountain Fire Sciences Laboratory, Missoula, MT.)

						Dead and down load by size class (inches)					Total dead and
Stand No.	Habitat type-phase	Age	Tree spp.	Canopy cover	Litter, duff depth	0-¼	¼-1	1-3	3+ sound	3+ rotten	down load
		Years		*Percent*	*Inches*	- - - - - - - -	- - - - - -	*Tons per acre*	- - - - - -	- - - - - -	- - - - - -
1B[a]	PIPO/FEID	110	PIPO	40	3.7	0.1	0.0	0.8	0.0	3.2	4.1
1C	PSME/SYAL	110	PSME	70	1.2	0.1	1.0	0.0	0.8	4.9	6.8
			PIPO	10							
1D	PIPO/SYAL	82	PIPO	60	3.3	0.1	0.0	1.9	8.0	0.0	10.0

[a]Refers to stand number in figure 11 and referenced in text.

Fires on Group One sites usually spread in fine fuels that dry quickly but are easily moistened by increasing humidity or precipitation. Opportunities for prescribed burning occur before greenup and after spring, when grasses begin to cure. Fires can move very fast, but they "collapse suddenly" when burning conditions abate (Williams and Rothermel 1992). Smoldering persists in deep litter deposits under old trees. In occasional witches' brooms formed by dwarf mistletoe, potential for torching and severe surface fire increase (Weir 1916). Grazing decreases fine fuels in Group One stands, thus decreasing the probable rate of fire spread in surface fuels (Arno and Gruell 1986); however, it does not lessen the likelihood of severe burning in tree crowns, regeneration, and accumulations of woody debris.

Role of Fire

Before the 20th century, Fire Group One sites were characterized by frequent underburns that eliminated most tree regeneration, thinned young stands, and perpetuated open stands dominated mainly by ponderosa pine. Studies in the South Fork Clearwater River and Salmon River drainages report fire return intervals in Group One stands ranging from 2 to 51 years and averaging about 15 to 20 years (table 17). No evidence of stand-replacing fire was found. Dry ponderosa pine stands in other areas have slightly shorter historic fire return intervals. In the Boise Basin, two stands in the PSME/SYAL habitat type had average fire return intervals of 10 and 18 years (Steele and others 1986). In forests of the Bitterroot Mountains, western Montana, fire return intervals in dry ponderosa pine stands averaged 9 years. Of the 75 fire years recorded in these stands, only one appeared to be stand-replacing (Arno 1976). Nonlethal fires on Group One sites often burned areas of 1,000 acres or more (Barrett 1984; Mutch 1992).

Davis and others (1980) suggested that frequent low-severity fires perform three main functions in dry forests like those of Fire Group One:

1. Maintain grasslands.
2. Maintain open forest structure. Periodic low-severity fires remove seedlings, reduce understory density, kill some overstory trees, and prune surviving trees.
3. Enhance tree regeneration, especially of ponderosa pine. Fire exposes mineral soil, reduces seedling-damaging insect populations, reduces competing vegetation, and increases nutrient availability. Depending on seed crop, postfire weather, and continuity of the seedbed, regeneration occurs as scattered individuals, dense stands, or a patchwork of thickets.

Fire exclusion has dramatically altered fire regimes in Fire Group One stands. Nonlethal surface fires, relatively easy to extinguish, have been nearly eliminated from all areas except the Selway-Bitterroot Wilderness. In seral grasslands, especially on gentle topography, tree reproduction indicates gradual expansion of forest cover. Aridity deters dense tree encroachment and heavy fuel accumulation (Barrett 1984), especially on steep slopes. Within Group One stands, canopy closure is slowly increasing. Where both Douglas-fir and ponderosa pine are present, loss of low-severity fire has favored Douglas-fir. Reconstructions of the historic structure and species composition of south-facing stands in the PSME/SYAL, PSME/AGSP, and PSME/*Festuca* habitat types on the Lolo National Forest, western Montana, illustrate some of the changes that have occurred in dry ponderosa pine stands during the past century (Habeck 1990). Prior to 1900, these sites supported about 13 large trees per acre, all ponderosa pine. The total density of trees greater than 3 inches d.b.h., both ponderosa pine and Douglas-fir, averaged about 38 per acre. In 1984, these sites supported 302 trees per

Table 17—Presettlement fire regimes for Fire Group One habitat types in northern Idaho. Locations of studies are shown in figure 1. Fire interval range lists minimum and maximum individual intervals from the study area. Mean fire interval and standard deviation (s.d.) are computed from stand mean fire intervals for the study area.

Location, habitat types, cover	Fire severity	Years: Fire interval range	Years: Mean fire interval	Years: S.d.	Number of stands
S. Fork Clearwater R.[a]					
—PSME/SYAL	Nonlethal	3-39	15	6	3
River of No Return[b]: PIPO & PSME/AGSP,/FEID,/SYAL					
—High elevation, 6,000 ft	Nonlethal	8-51	22	4	5
—Low elevation, <5,000 ft	Nonlethal	3-30	15	2	6
—Salmon River corridor	Nonlethal	2-39	14	12	6

[a]Barrett (1993).
[b]Barrett (1984).

acre larger than 3 inches d.b.h., and smaller seedlings and saplings were even more dense (averaging 106.5 in a 0.18 acre plot). Douglas-fir dominated every size class except the largest.

Where deep duff or heavy woody fuels have accumulated in Group One stands, the potential for lethal underburns has increased. Where regeneration has grown into the crowns of mature trees, the potential for torching and crown fire has increased.

Forest Succession

In presettlement times, forests in Fire Group One were usually open and dominated by ponderosa pine. Douglas-fir may regenerate during intervals between fires; its longevity depends on the subsequent fire regime. Steele and Geier-Hayes (1994) described potential successional communities for the PSME/SPBE habitat type in central Idaho that contain quaking aspen and lodgepole pine as well as ponderosa pine and Douglas-fir. Their report included a detailed description of potential understory communities in early, middle, and late successional stages. Our diagram of succession in Fire Group One (fig. 12) is based on autecological characteristics of the dominant tree species. It illustrates succession for sites in the Douglas-fir series; when applying it to sites in the ponderosa pine series, all species references should be to ponderosa pine. (Subsequent letters and numbers in this section refer to fig. 12.)

Prior to the 20th century, most Group One sites were open forests with occasional patches of shrubs, dominated by large, old ponderosa pines (D2). Periodic low-severity fire thinned or removed tree regeneration, thus perpetuating this state. A fast-spreading fall wildfire in grassy fuels in the PIPO/AGSP habitat type, in the Selway-Bitterroot Wilderness, was followed by very high production of annual species (Merrill and others 1980). By the fourth postfire year, biomass production by perennials on burned plots had increased to levels greater than that on unburned plots. Fire favored an exotic annual grass, *Bromus tectorum*, as well as *Pseudoroegneria spicata*, *Koeleria cristata*, and *Achillea millefolium*. Concentrations of several minerals were lower in plants on burned plots during the first postfire year. In adjacent stands with understory shrubs (PIPO/SYAL habitat type), species composition was changed little after burning. Shrub density and biomass production increased during the first four postfire years (Merrill 1982).

Because stand-replacing fires in undisturbed Group One stands have been unusual, little is known about natural succession after severe fire. Most grasses, forbs, and shrubs resprout within the first postfire year (A). Given an adequate seed crop and sufficient moisture, tree seedlings become established (B1). By

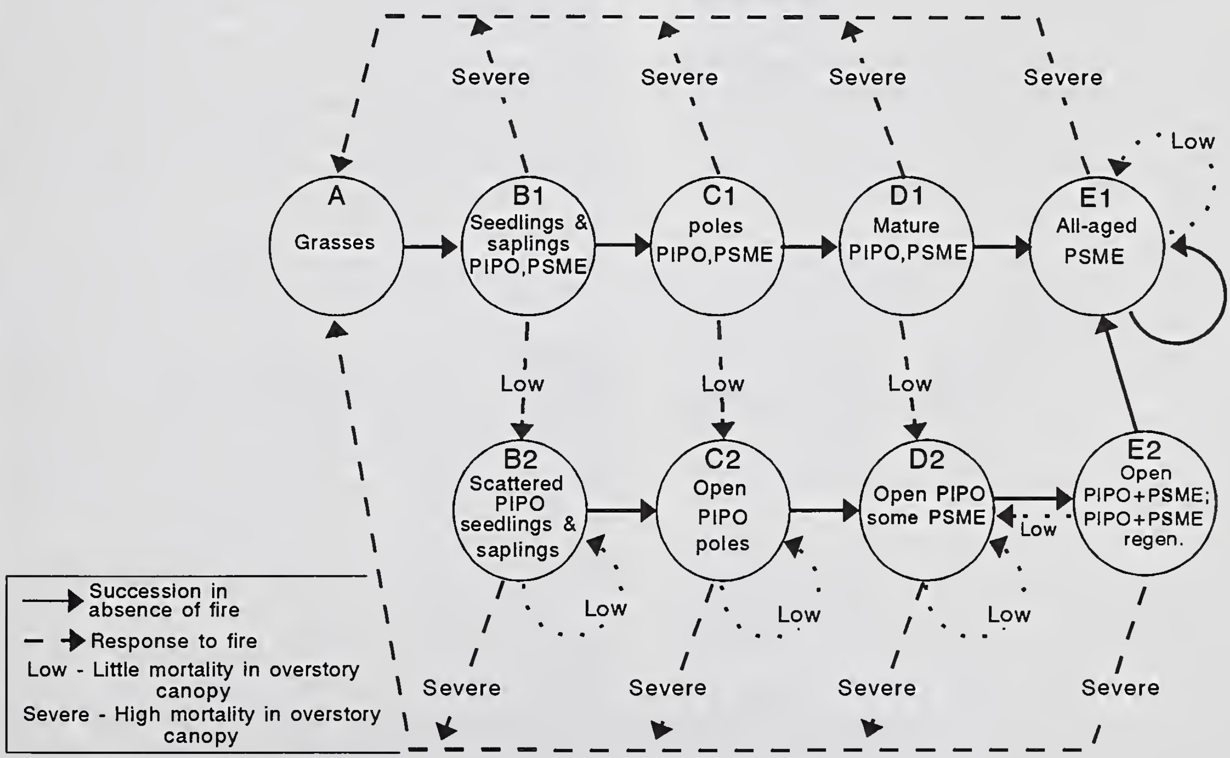

Figure 12—Hypothetical fire-related successional pathways for Fire Group One habitat types in the Douglas-fir series.

the time ponderosa pine seedlings are 2 inches d.b.h., some can withstand low-severity fires, which create a very open stand of ponderosa pine and eliminate Douglas-fir (B2). Fires of higher severity—unlikely in natural fuels but possible on harvested sites—would kill all saplings and return the stand to the grass stage (A). In addition, severe fire at this stage would decrease soil nutrient reserves and increase erosion, impeding subsequent tree establishment.

Without fire, Group One stands develop to the pole stage (C1) and mature forest (D1). Because tree establishment is episodic and slow, stands may be uneven-age or may consist of numerous even-age clusters of trees. Low-severity fires thin the pines and remove most of the Douglas-fir (C2, D2). At maturity, Group One stands become susceptible to root disease, dwarf mistletoe, and pine beetle infestations; these disturbances open the stand, diversify its age structure, and may increase Douglas-fir dominance (E1, E2). They may also increase surface fuels and potential fire severity.

If undisturbed, Group One forests could theoretically develop to climax status (E1). However, true climax stands of Douglas-fir, with no evidence of large, old ponderosa pines, are difficult to find. Likewise, true climax stands of ponderosa pine, without Douglas-fir in the understory, are rare in northern Idaho.

Fire Management Considerations

Lightning produces relatively frequent ignitions in Fire Group One stands. Even in wilderness areas, however, the area burned by prescribed natural fires is likely to be considerably less than that burned in presettlement times, and fires are likely to be more severe. Brown and others (1994) have compared the extent of fire in the Selway-Bitterroot Wilderness during presettlement times with the extent of fire in recent years (since 1979, when prescribed natural fire was first included as a management option in the Selway-Bitterroot). In their ponderosa pine fire regime type, which includes stands in the PSME/SYAL habitat type, the average area burned per year in presettlement times was probably (95 percent confidence interval) between 5,965 and 9,671 acres; the 95 percent confidence interval for recent years was much less, 193 to 4,127 acres. Of the area burned in recent years, 26 percent has been in stand replacement fire; there was no evidence that stand replacement fire occurred in the ponderosa pine fire regime type during presettlement times. In wilderness areas where the current time between fires far exceeds the presettlement average fire-free interval, management-ignited prescribed burns can be considered to meet wilderness goals (Brown 1992-1993).

Fire can be used in Group One stands to enhance forage, maintain grassland or open forest, reduce fuels, and enhance tree regeneration. A combination of prescribed fire and thinning has been recommended for restoring ponderosa pine dominance in the Boise National Forest (Morelan and others 1994). Prescription windows for management-ignited fire have been described for grasslands invaded by Douglas-fir in Montana (Gruell and others 1986) and for ponderosa pine stands with grassy understories in Oregon, Idaho, and Montana (Kilgore and Curtis 1987); their recommendations are summarized in table 18.

Many Group One sites are grazed by livestock during the summer and used by elk and mule deer in the winter. Grazing decreases fine fuels and increases tree regeneration (Arno and Gruell 1986). Prescribed fire can be used to eliminate trees, increase forage

Table 18—Ranges of conditions for prescribed burning in grasslands invaded by Douglas-fir and for underburns in ponderosa pine with grass understory.

Cover	Average windspeed	Cloud cover	Temperature	Relative humidity	Fuel moisture 1 hr	Fuel moisture 10 hr	Fuel moisture 100 hr	Time of year
	mi/hr	*Percent*	*°F*	*Percent*	*Percent*	*Percent*	*Percent*	
Sagebrush, grass, Douglas-fir seedlings or saplings[a]	3-12	0-10	50-80	15-40	6-12	8-15	—	Spring, fall
Douglas-fir poles in sagebrush and grass[a]	3-8	0-20	50-75	25-60	6-15	8-18	—	Fall
Ponderosa pine with grass understory[b]	5-10	—	60-70	25-35	6-14	8-18	15-40	Spring, fall

[a]Ranges of conditions that allow fire to carry in grasslands invaded by big sagebrush and Douglas-fir in the Deerlodge National Forest, MT (Gruell and others 1986). Prescription windows for individual burns may be smaller to satisfy local fuel and terrain conditions. Wind speed measured at 20 feet above vegetation.
[b]Ranges of conditions preferred by experienced burners for underburns in ponderosa pine with grassy understory occurring in Oregon, Idaho, and Montana (Kilgore and Curtis 1987). Wind speed measured at midflame height.

production, and enhance the nutritional value of forage. Where fuels are sparse, grazing must be eliminated for at least a year before burning to develop sufficient fine fuel to carry a fire. In Montana grasslands invaded by Douglas-fir, Gruell and others (1986) recommended burns of 1,000 acres or more and restriction of grazing for at least 1 year after burning. Smaller burns, especially those less than 80 acres, are more expensive to complete than larger burns and are difficult to protect from excessive grazing during the first postfire year.

Underburning, often in combination with partial cutting, can be used to maintain vigorous, open ponderosa pine stands. These conditions enhance ponderosa pine growth and discourage infestation by mountain pine beetle. Underburning can also be used to favor ponderosa pine reproduction over Douglas-fir, if pine seed is plentiful (Foiles and Curtis 1973). Plantings are more likely to succeed than natural regeneration, although subsequent dry years can cause high mortality. After saplings are 10 to 12 feet tall, periodic underburning can be used to thin, eliminate regeneration, and reduce woody fuels and duff (Wright 1978). Thinning fires produce variable effects and thus could be used to increase structural diversity within stands. In north-central Oregon, a low-severity fall fire in ponderosa pine produced 86 percent mortality among trees less than 10 feet tall and more than 50 percent mortality among trees 10 to 20 feet tall (Wooldrige and Weaver 1965).

Broadcast burning after harvesting can recycle nutrients and control the severe competition for moisture typical of Fire Group One sites (Ryker and Losensky 1983). In central Idaho, ponderosa pine and Douglas-fir establish most readily in the PSME/SPBE habitat type where some tree or shrub cover is available and duff has been removed; moss and rotten wood are the most successful seedbeds (Steele and Geier-Hayes 1994). Studies of ponderosa pine and bunchgrass habitat types in Arizona indicated that, after establishment, seedlings on burned sites grow faster than seedlings on unburned sites, apparently because of slower drying rates 6 to 12 inches below the soil surface (Harrington 1991). Mechanical disturbances should be minimized to prevent damage to thin, rocky soils.

Severe fire on Group One sites reduces soil and nutrient reserves and impedes tree regeneration. It also reduces woody debris, the source of soil wood. Management-ignited fire can be used to decrease ladder and surface fuels and thereby reduce the potential for severe fire. If heavy fuels have accumulated at the bases of mature trees, or if mortality from pine beetle infestation has been high, successive low-severity burns may be needed to avoid excessive overstory mortality and soil degradation. In central Oregon, first-entry burns have been conducted using narrow strip headfires that produce short flame lengths and only partial fuel reduction. Desired fuel reduction is obtained by at least one fire conducted later under drier burning conditions. Burning costs and damage potential are dramatically lower after the first burn (Maupin 1981).

Heavy fuel loads can also be reduced through firewood removal, thinning operations, and piling and burning. Lopping and scattering, without subsequent burning, generally increase the potential for severe fire because needles and slash compact and decompose slowly. Data from ponderosa pine stands in central Washington indicate that spring burns can decrease the depth of a ponderosa pine fuel bed as much as 8 years of settling without fire, and fall burns can decrease fuel bed depth as much as 20 years of settling without fire (Carlton and Pickford 1982).

Fire Group Two: Warm, Dry to Moderate Douglas-fir, Grand Fir, and Ponderosa Pine Habitat Types

Abies grandis/Physocarpus malvaceus h.t.-*Coptis occidentalis* phase (ABGR/PHMA-COOC), grand fir/ninebark-western goldthread phase*

Abies grandis/Physocarpus malvaceus h.t.-*Physocarpus malvaceus* phase (ABGR/PHMA-PHMA), grand fir/ninebark-ninebark phase*

Abies grandis/Spiraea betulifolia/h.t. (ABGR/SPBE), grand fir/white spiraea*

Pinus ponderosa/Physocarpus malvaceus h.t. (PIPO/PHMA), ponderosa pine/ninebark*

Pseudotsuga menziesii/Carex geyeri h.t. (PSME/CAGE), Douglas-fir/elk sedge

Pseudotsuga menziesii/Calamagrostis rubescens h.t.-*Arctostaphylos uva-ursi* phase (PSME/CARU-ARUV), Douglas-fir/pinegrass-kinnikinnik phase+

Pseudotsuga menziesii/Calamagrostis rubescens h.t.-*Calamagrostis rubescens* phase (PSME/CARU-CARU), Douglas-fir/pinegrass-pinegrass phase

Pseudotsuga menziesii/Physocarpus malvaceus h.t.-*Physocarpus malvaceus* phase (PSME/PHMA-PHMA), Douglas-fir/ninebark-ninebark phase*

Pseudotsuga menziesii/Physocarpus malvaceus h.t.-*Smilacina stellata* phase (PSME/PHMA-SMST), Douglas-fir/ninebark-starry Solomon-plume phase*

Pseudotsuga menziesii/Vaccinium caespitosum h.t. (PSME/VACA), Douglas-fir/dwarf huckleberry+

Pseudotsuga menziesii/Vaccinium globulare h.t. (PSME/VAGL), Douglas-fir/blue huckleberry+

*Likely to be maintained as persistent shrubfields if burned by severe fire at intervals shorter than 30 years.

+May be dominated in early succession by lodgepole pine; information not specific to this fire group is in "Seral Lodgepole Pine in Northern Idaho."

Where PSME/VAGL stands occur adjacent to dry subalpine stands, their fire ecology resembles that of Fire Group Four.

Vegetation

Fire Group Two consists of warm habitat types in the Douglas-fir, ponderosa pine, and grand fir series that can support a dense layer of tall shrubs or a dense sward of *Carex geyeri* or *Calamagrostis rubescens* (fig. 13, table 19). The overstory of mature forests is somewhat open, although canopy cover often exceeds 50 percent. Dense Douglas-fir or grand fir regeneration often develops in the understory. Group Two stands are most often found on southeast- to southwest-facing slopes, although they occur on some north-facing slopes in the Nez Perce and Clearwater National Forests. PSME/VACA occurs in frost pockets, mainly in the Purcell Trench (the wide, nearly straight topographic trough that extends from Coeur d'Alene north into British Columbia) (Alt and Hyndman 1989). Group Two sites are diverse but, except for the PSME/PHMA and ABGR/PHMA habitat types, have limited coverage in northern Idaho.

Ponderosa pine dominates early postfire succession in Fire Group Two, accompanied by Douglas-fir. Where moisture is plentiful, western larch codominates. Lodgepole pine dominates some seral stands in the Purcell Trench. Grand fir is minor in early seral stands, but may eventually dominate in the ABGR/PHMA and ABGR/SPBE habitat types.

Figure 13—Vegetation and fuels in Fire Group Two. A. Stand 2A, nearly closed forest in PSME/PHMA-PHMA habitat type on steep, northeast-facing slope, Salmon River District, Nez Perce National Forest. Most trees are medium-sized Douglas-fir. Photo by Jim Mital. B. Stand 2B, PSME/PHMA-PHMA habitat type on southeast-facing slope in Sandpoint Ranger District, Kaniksu National Forest. Overstory dominants are Douglas-fir; ponderosa pine and Douglas-fir regeneration are present. C. Stand 2C, ABGR/PHMA-PHMA habitat type on southwest-facing slope, Selway Ranger District, Nez Perce National Forest. Overstory contains medium and large ponderosa pine and Douglas-fir, and a few grand fir. D. Northwest-facing stand of medium Douglas-fir in PSME/PHMA-PHMA habitat type, Salmon River District, Nez Perce National Forest.

Table 19—Stand characteristics and fuel loadings in some Fire Group Two stands. Fuel loadings are in tons/acre. Stand 2A is shown in figure 13. Stand 2E is on a south-facing slope, Bonners Ferry Ranger District, Kaniksu National Forest. Stand 2F faces southwest (St. Maries District, St. Joe National Forest). Stand 2G faces northeast (Salmon River District, Nez Perce National Forest). Data on last line ("stand" 2H) are average fuel loadings in ungrazed stands on slopes less than 35 percent in Latah County, ID (Zimmerman 1979). (Data for Stands 2A and 2E-2G were provided by Jim Mital and are on file at Intermountain Fire Sciences Laboratory, Missoula, MT.)

Stand No.	Habitat type-phase	Age	Tree spp.	Canopy cover	Litter, duff depth	Dead and down load by size class (inches) 0-¼	¼-1	1-3	3+ sound	3+ rotten	Total dead and down load
		Years		*Percent*	*Inches*	*Tons per acre*					
2A[a]	PSME/PHMA-PHMA	90	PSME PIPO	80 1	2.0	0.0	1.3	1.1	0.0	0.6	3.0
2E	PSME/PHMA-PHMA	85	PSME PIPO	60 10	1.5	0.1	0.7	1.1	0.0	0.0	1.9
2F	ABGR/PHMA-PHMA	85	PSME PIPO ABGR	60 3 1	2.2	0.0	0.8	1.8	1.2	0.0	3.8
2G	PSME/PHMA-PHMA	115	PSME	60	2.7	0.1	0.4	1.5	3.8	10.3	16.1
2H	PSME/PHMA[b]	—	PSME, PIPO		—	0.2	0.4	0.6	2.2	3.2	6.6

[a]Refers to stand number in text.
[b]Average duff loading: 23.6 tons per acre.

Physocarpus malvaceus, *Holodiscus discolor*, *Acer glabrum*, *Amelanchier alnifolia*, *Spiraea betulifolia*, and *Symphoricarpos albus* contribute to a distinct, sometimes dense shrub layer on Group Two sites throughout succession. *Crataegus douglasii* occurs on relatively dry sites. *Salix scouleriana* may dominate seral stands (Steele and Geier-Hayes 1989). Early in succession, Group Two stands have great diversity and high coverage of shrubs, including the above species and also *Arctostaphylos uva-ursi*, *Mahonia repens*, *Ceanothus* species, *Philadelphus lewisii*, *Prunus* species, *Ribes cereum*, *Ribes lacustre*, *Rosa gymnocarpa*, *Rosa woodsii*, and *Rubus parviflorus* (Cooper and others 1991; Jones 1995; Steele and Geier-Hayes 1989, 1993).

Herbs are also plentiful and diverse in Fire Group Two. *Bromus vulgaris* is present on most sites. The introduced species *Bromus tectorum* may thrive on heavily grazed or disturbed sites. A dense sward of *Calamagrostis rubescens* or *Carex geyeri* may form early in succession and persists in a few habitat types; usually it gives way to a mixture of herbs and shrubs. Important forbs include *Achillea millefolium*, *Adenocaulon bicolor*, *Anemone piperi*, *Arenaria macrophylla*, *Arnica cordifolia*, *Erythronium grandiflorum*, *Fragaria* species, *Galium boreale*, *Galium triflorum*, *Osmorhiza chilensis*, and *Polystichum munitum*. *Xerophyllum tenax* occurs in many stands.

Fuels

Forests in Fire Group Two tend to be more productive and have heavier loadings of downed woody fuels than forests in Fire Groups One and Three. Total dead and downed woody fuel loadings in PSME/PHMA-PHMA stands in the Selway-Bitterroot Wilderness average 8.4 tons per acre (Walker 1973); two PSME/PHMA stands near Tensed, ID, had loadings of less than 7.6 tons per acre (Johnsen 1981). Fuel loadings vary greatly (table 19). In mature PSME/PHMA-PHMA stands in Montana, Fischer (1981b) found total woody fuel loadings ranging from 2.5 tons per acre, in a stand dominated by 214 year old ponderosa pine and 57 year old Douglas-fir, to 27.3 tons per acre in a stand dominated by 230 year old Douglas-fir. Dense regeneration increases fuel loadings, as do natural thinning, snow breakage, blowdown, and insect and disease mortality.

Relatively deep duff, containing considerable rotting wood, develops during succession in Fire Group Two. Brown and Bradshaw (1994) described fuel models for stands in Fire Groups One and Two in the Selway-Bitterroot Wilderness. To represent open ponderosa pine stands in presettlement times, they used the following loadings for surface fuels (tons per acre): litter, 0.6; duff, 2.3; herbs, 0.2; shrubs, 0.4; and tree regeneration, 0.2. The fuel models indicate that duff loading is nearly four times as heavy in current stands

as it was in presettlement stands. As dominance shifts during succession from ponderosa pine to Douglas-fir, litter flammability also changes; pine litter is more loosely packed and dries more quickly than fir litter, which may not carry a surface fire until midsummer (Christensen 1988). Duff and downed woody fuels tend to be heavier, and fine herbaceous fuels lighter, in grazed than ungrazed stands (Zimmerman 1979; Zimmerman and Neuenschwander 1984). Harvesting in Group Two stands can produce total downed woody fuel loadings exceeding 30 tons per acre (Morgan and Shiplett 1989).

On Group Two sites recently underburned, fine fuels consist mainly of litter and light duff. As time since fire increases, a dense growth of tall shrubs develops. Stand 2A (fig. 13) shows a luxuriant undergrowth of shrubs and forbs that can retard fire spread under moderately moist conditions. Woody fuels are relatively light in this young stand (table 19). Stand 2B (fig. 13) is open; shrubs and regeneration reach into the tree crowns only occasionally, so crown fire is unlikely. Stand 2C burned in the 161,000 acre Pete King Fire of 1934 (described in Pyne 1982). This stand has a dense shrub layer and a high, very open overstory containing ponderosa pine, Douglas-fir, and grand fir; all mature trees are fire scarred. In stand 2D, deep litter and dead branches near the ground contribute to the potential for severe fire. The Douglas-fir overstory is not continuous, however, so crown fire is likely only with strong winds.

Keane and others (1989) used the FIRESUM model to predict changes in fuel loadings over time in a moist PSME/PHMA-PHMA stand in western Montana. With fires modeled at 20 year intervals, litter fluctuated from about 0.4 to 1.8 tons per acre and duff fluctuated from 0 to 0.8 inches in depth. With no fires occurring for 100 years, litter loading exceeded 5.5 tons per acre and duff depth reached about 1.7 inches. Modeled loadings of dead and downed woody fuels 0 to 1 inch in diameter fluctuated from 0.8 to 3.4 tons per acre with 20 year fire return intervals and stabilized at about 3.6 tons per acre after 30 years without fire. Larger dead and downed fuels were not described. Predicted height of crown scorch was highest when fuel loadings were high.

Role of Fire

Prior to the 20th century, many stands in Fire Group Two were burned frequently by low- or mixed-severity fire; occasional stand-replacing fire occurred as well. Where fires occurred at relatively short intervals (less than 25 years), they were mostly nonlethal (table 20). In the Selway-Bitterroot Wilderness, Barrett and Arno (1991) found a mean fire return interval of 23 years. Fire behavior was mostly nonlethal, but patches of stand replacement also occurred. Fire severity tended to be greater where fire-free intervals were longer. A presettlement history of mixed fire severities was found in PSME/PHMA stands in the South Fork Clearwater River drainage (Barrett 1993) and Selway Ranger District (Green 1994), Nez Perce National Forest. Nonlethal fires occurred at average intervals of 31 years on northerly slopes in the River of No Return Wilderness, where lethal fires also occurred—at intervals greater than 50 years (Barrett 1984).

Fire regimes in Group Two habitat types from areas outside northern Idaho resemble those reported in table 20. In the Boise Basin of central Idaho, Steele and others (1986) found mean fire return intervals ranging from 10 to 22 years in PSME/PHMA and PSME/CAGE habitat types. In the Bitterroot Mountains of western Montana, 64 percent of 128 historic fires on “montane slopes” (PSME/PHMA, /CARU, /VAGL, and /SYAL habitat types) were recorded by fire scars without stand replacement, indicating low severity; 34 percent were recorded by fire scars with some tree regeneration, and 2 percent were recorded only by tree regeneration, indicating stand replacement (Arno 1976). On similar stands in western Montana, fires at mean intervals of less than 50 years account for the presence of old growth ponderosa pine (Arno and others 1995). All-age structures were produced by nonlethal fire regimes, and even-age structures were produced by fire regimes with a combination of nonlethal fire and patchy, severe fire.

Frequent, low- and mixed-severity fires control structure and species composition in Group Two stands. Ponderosa pine reproduces well in fire-created openings if seed is available and moisture is plentiful. Douglas-fir and western larch may also reproduce well, depending on moisture conditions. Underburns thin regeneration, removing Douglas-fir and grand fir and leaving few ladder fuels (Habeck 1990). Mountain pine beetle irruptions are uncommon in open stands of ponderosa pine, and root disease centers are small because grand fir and Douglas-fir, the more susceptible species, are reduced by fire (Habeck 1990; Wickman 1992).

Long fire-free intervals favor Douglas-fir and grand fir regeneration in Group Two stands. A study of the historic structure and species composition of north-facing PSME/PHMA stands in western Montana (Habeck 1990) illustrated some of the changes that have occurred in Fire Group Two during the past century. Ecology and succession on these stands probably resemble those on many PSME/PHMA-SMST stands in northern Idaho. Prior to 1900, the study area supported about 27 large trees per acre, with ponderosa pine and western larch codominant. The total density of trees greater than 3 inches d.b.h. averaged 43 per acre. In 1984, these sites supported 211 trees

Table 20—Presettlement fire regimes for Fire Group Two habitat types in northern Idaho. Locations of studies are shown in figure 1. Fire interval range lists minimum and maximum individual intervals from the study area. Mean fire interval and standard deviation (s.d.) are computed from stand mean fire intervals for the study area.

Location, habitat types, cover	Fire severity	Years: Fire interval range	Years: Mean fire interval	Years: S.d.	Number of stands
Selway-Bitterroot Wilderness[a]:					
—PSME/PHMA,/SYAL; ABGR/PHMA	Nonlethal underburns, occasionally lethal		23	8	11
—PSME/PHMA, ABGR/PHMA, mostly shrubfields	Lethal		54		1
Selway Ranger District, Nez Perce National Forest[b]:					
—PSME/PHMA, PIPO-PSME cover	Mixed	23-115	62		2
S. Fork Clearwater R.[c]: PSME/PHMA					
—PSME-ABGR cover	Lethal and mixed		138		1
—PIPO-PSME-ABGR cover	Nonlethal and mixed	4-160	48	36	13
—PIPO-PSME cover	Nonlethal	5-42	19	5	3
River of No Return[d]: PSME/CARU,/PHMA					
—high elevation, 6,000 ft	Nonlethal	5-52	22	8	5
—low elevation, <5,000 ft	Nonlethal	3-35	12	2	4
—Salmon River corridor, NW to NE aspects	Mixed - nonlethal	9-95	31	15	3
	- lethal		>50		
Cook Mtn., Clearwater National Forest[e]:					
—PSME & ABGR series, mostly shrubfields	Mostly lethal underburns and crown fire	9-78	29	11	7

[a]Barrett and Arno (1991), Brown and others (1994, 1995).
[b]Green (1994).
[c]Barrett (1993).
[d]Barrett (1984).
[e]Barrett (1982). Includes stands in both Fire Group Two and Fire Group Seven.

per acre larger than 3 inches d.b.h., and Douglas-fir dominated every size class except the largest.

Twentieth century fire exclusion has not produced conditions completely different from those in earlier times; historically, fires were infrequent in some Group Two stands and stand-replacing fire occurred at least occasionally. What has changed is the geographic extent and continuity of these conditions. The cover and density of Douglas-fir and grand fir in PSME/PHMA stands have increased for several reasons, including fire exclusion, selective harvesting of ponderosa pine and western larch, and poor pine regeneration after harvesting (Arno and others 1985). Increased density, and lack of pruning and duff reduction by fire, have increased the potential for crown fire and severe underburning in habitat types like those of Group Two throughout the Northern Rocky Mountains and Intermountain Region (Habeck 1990; Hall 1976; Mutch and others 1993; Steele and others 1986). Other aspects of stand dynamics have also changed. Tree growth is likely to be slowed (Hall 1976). Stands containing dense regeneration tend to support larger numbers of mountain pine beetle (in ponderosa pine), higher populations of western spruce budworm and Douglas-fir tussock moth, and larger root disease centers than open stands dominated by large pines (Anderson and others 1987; Hall 1976; Williams and Marsden 1982).

Some sites in Fire Group Two have burned in severe wildfires at intervals of 25 to 60 years (table 20). In the Cook Mountain area, Clearwater National Forest, Barrett (1982) documented a history of severe reburns dating back at least 350 years. Tree regeneration after reburns varies, but it may be extremely slow on dry sites. In an area of the Coeur d'Alene National Forest that burned in 1870 and again in 1910, Larsen (1925) found 1,313 tree seedlings per acre on a north-facing slope, but only 58 seedlings per acre on a south-facing slope. He described the south-facing slope as "typical... the result of hard double burns... thin rocky soil, much sod, grass, and patches of snow brush [*Ceanothus velutinus*]...." Even where Douglas-fir survived both fires and seed was available, tree regeneration was sparse. See "Persistent Seral Shrubfields."

No literature is currently available on the fire ecology of lodgepole pine-dominated stands in Fire Group Two. For a general description of the role of fire in seral lodgepole pine stands, see "Seral Lodgepole Pine in northern Idaho."

Forest Succession

Studies describing forest succession in Group Two habitat types in northern Idaho have not been published, but extensive successional research has been conducted in similar habitat types in adjacent areas. Succession in the PSME/PHMA and PSME/CARU habitat types in central Idaho was described by Steele and Geier-Hayes (1989, 1993). Succession in PSME/PHMA and PSME/VAGL stands in western Montana was described by Arno and others (1985) and Crane and others (1983). Our descriptions of succession are based on these reports, descriptions of species composition of mature stands (especially Cooper and others 1991), and references to autecological characteristics of dominant tree species.

After stand-replacing fire, annuals and other short-lived species colonize Group Two sites immediately; but within 5 years, perennial herbs and shrubs dominate (Steele and Geier-Hayes 1989, 1993). Research on north-facing PSME/PHMA-PHMA stands in northern Idaho (Cholewa and Johnson 1982) indicated that the following herb and shrub species increase after disturbance by logging or fire: *Acer glabrum*, *Calamagrostis rubescens*, *Ceanothus sanguineus*, *Epilobium* species, *Galium boreale*, *Heuchera cylindrica*, *Pseudoroegneria spicata*, *Rubus parviflorus*, *Salix scouleriana*, *Spiraea betulifolia*, and *Symphoricarpos albus*. Drew (1967) found many of the same shrub species dominating a 5 year old burn on sites east of Coeur d'Alene, ID, that included PSME/PHMA stands. *Ceanothus* species can dominate PSME/PHMA stands in western Montana for 50 years after fire (Arno and others 1985). *Salix scouleriana*, common after severe fire, may persist in forest openings because of its tall stature (Steele and Geier-Hayes 1989). *Vaccinium globulare* occurs in PSME/PHMA stands in central Idaho (Steele and others 1989); it occurred at low densities within 5 years of severe fire in PSME/PHMA and /VAGL stands in western Montana (Crane and others 1983). Many shrubs can dominate in early successional stages and persist, at somewhat reduced coverage, in mature forests. These include *Amelanchier alnifolia*, *Holodiscus discolor*, *Physocarpus malvaceus*, and *Spiraea betulifolia*. Herbaceous species important in various successional stages in central Idaho have been listed for the PSME/PHMA and PSME/CARU habitat types by Steele and Geier-Hayes (1989, 1993).

Forest development after fire depends, to a great extent, on site conditions. The warmest sites (typically PIPO/PHMA and PSME/PHMA-PHMA habitat types) are dominated either by ponderosa pine alone or by ponderosa pine and Douglas-fir (Pathway 2.1, fig. 14).

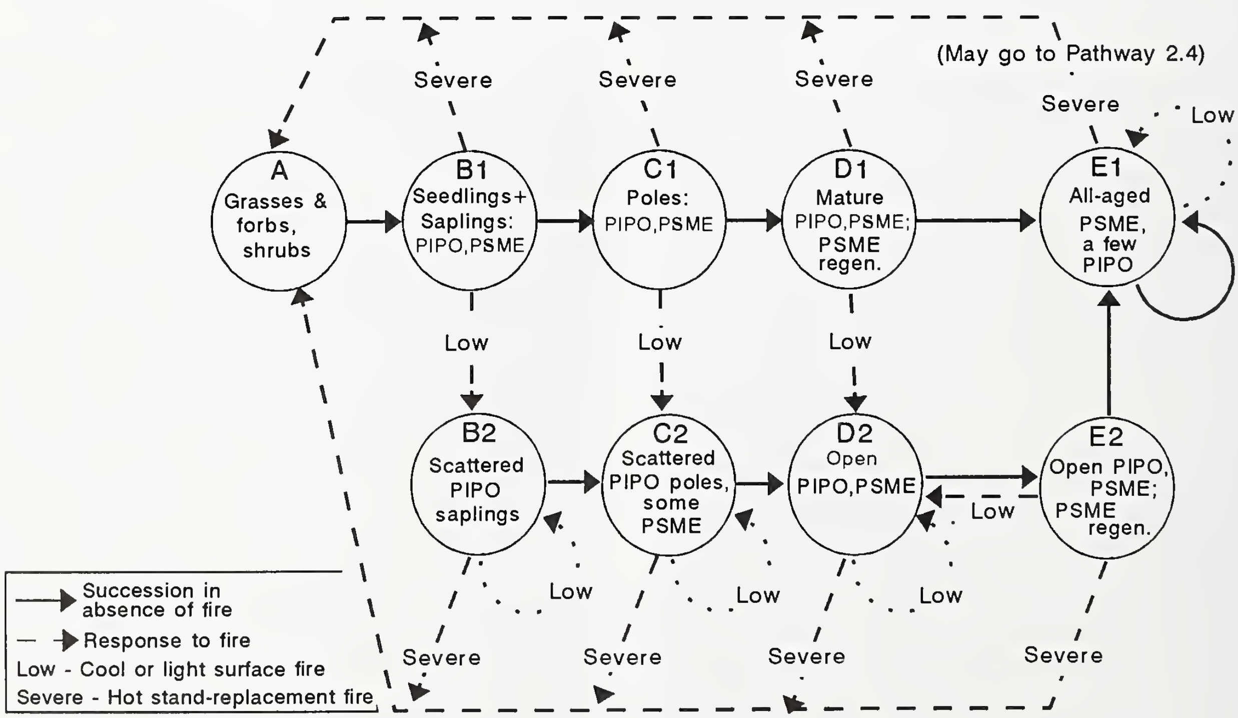

Figure 14—Successional Pathway 2.1. Hypothetical fire-related succession for Fire Group Two habitat types where ponderosa pine and Douglas-fir are the dominant seral species. Grand fir may be present in stages C1-E1. For stands in the ponderosa pine series, change all tree species references to ponderosa pine.

This pathway corresponds to the "dry phase" of the PSME/PHMA habitat type described for western Montana by Arno and others (1985). Where conditions are cooler and more moist, particularly in the PSME/PHMA-SMST habitat type in the Idaho Panhandle National Forests, western larch is an important seral species (Pathway 2.2, fig. 15). This pathway resembles the "moist phase" of PSME/PHMA described by Arno and others (1985). Two additional successional patterns occur in some Group Two stands but, due to their limited extent in northern Idaho, or limited literature describing them, are not described in detail here. On Group Two sites with unusually frosty conditions, lodgepole pine dominates early succession (Pathway 2.3). Where ponderosa pine, western larch, and lodgepole pine have declined or failed to reproduce, Douglas-fir dominates all stages of forest development (Pathway 2.4).

The successional pathways described here are qualitative guides. Since stand development varies with seed source, presence and vigor of pathogens, and disturbance history, actual succession on a given site may follow a path intermediate between or diverging from those described here.

Pathway 2.1. Succession Dominated by Ponderosa Pine and Douglas-fir—Prior to widespread fire exclusion, most of these sites were burned frequently by low-severity fire, which maintained a high, open canopy (fig. 14 D2). (Subsequent references in this section are to fig. 14.)

Herbs and shrubs recover quickly after most fires (A). Tree regeneration, mainly ponderosa pine and Douglas-fir (B1), is episodic. Ponderosa pine apparently does not establish as well after stand removal as it did in a regime of frequent underburning (Arno and others 1985). Douglas-fir establishes well where protection is available from rocks, logs, shrubs, or standing trees. Natural regeneration requires 20 years or more on dry PSME/PHMA sites in western Montana

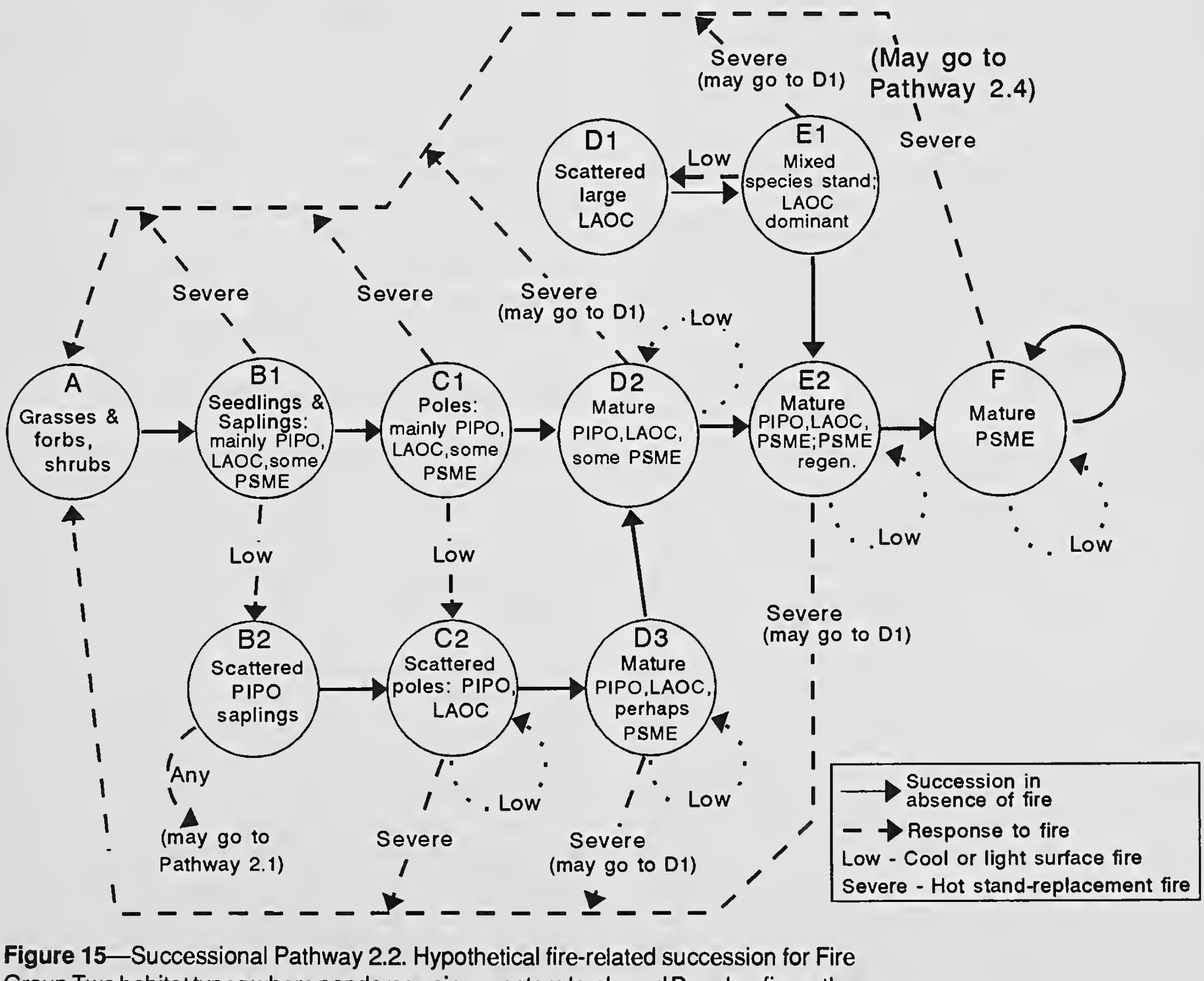

Figure 15—Successional Pathway 2.2. Hypothetical fire-related succession for Fire Group Two habitat types where ponderosa pine, western larch, and Douglas-fir are the dominant seral species. Grand fir may be present in stands without frequent fire (for example, stage D2), and may eventually dominate stage F.

(Arno and others 1985). Conditions favoring natural regeneration may occur infrequently; some PSME/CARU sites in central Idaho require nearly a century to regenerate naturally (Steele and Geier-Hayes 1993).

Some ponderosa pine saplings (with basal diameter greater than 2 inches) survive low-severity fire (B2). Fires of higher severity kill all saplings and return the stand to herbs and shrubs (A). Low-severity fire in the pole stage (C1) thins the ponderosa pines and leaves some Douglas-fir (with basal diameter greater than 4 inches) (C2). Low-severity fire in a mature stand (D1) removes tree regeneration and thins the overstory, producing an open structure (D2). Frequent, low-severity burns perpetuate ponderosa pine dominance and often favor ponderosa pine regeneration. With less frequent fire, Douglas-fir regeneration matures (E2). Very long fire-free intervals produce a mature stand with few ponderosa pines (E1). Large Douglas-fir survive low-severity fire, but dense understory and ladder fuels enhance the potential for severe fire, which would return the stand to grasses and forbs (A).

Pathway 2.2. Succession With Ponderosa Pine, Douglas-fir, and Western Larch—Prior to the 20th century, most stands in this pathway underburned frequently enough to maintain an open structure dominated by ponderosa pine and western larch (fig. 15 D3). (Subsequent references in this section are to fig. 15.) Occasional stand replacement occurred, often in patches within nonlethal burns.

When stand-replacing fire removes the overstory in this pathway, herbs and shrubs recover quickly (A). Tree regeneration is usually established within 20 years (B1), consisting mainly of ponderosa pine, western larch, and Douglas-fir. The sites in this pathway are too dry for prolific grand fir or western white pine regeneration and too warm for lodgepole pine to dominate.

Low-severity fire in the sapling stage (B1) removes all tree regeneration except scattered ponderosa pine (B2). If western larch seed is available, stand development continues to follow this pathway; if not, the stand follows Pathway 2.1. Low-severity fire in the pole stage (C1) leaves an open stand of ponderosa pine and western larch (C2). Frequent low-severity fire can maintain this open structure, dominated by ponderosa pine and western larch, for centuries (D3). Mature Douglas-fir withstand low-severity fire, so mature stands often contain all three species (D3). Ponderosa pine and western larch regenerate well in severely burned patches, near edges, and under a very open canopy, while Douglas-fir regenerates under greater cover.

Mature western larch (D2, D3) can withstand severe fire, especially if open-grown and sheltered from extreme fire behavior by topographic features or meteorological conditions. When severe fire leaves isolated western larch survivors (relict trees) (D1), they dominate subsequent stand development (E1). Recurring fires increase western larch dominance; succession without fire eventually leads to a mature stand of Douglas-fir (E2, F).

If fire is excluded for a very long time, ponderosa pine and western larch gradually decline. Douglas-fir persists in the overstory and reproduces well (F), accompanied by grand fir on sites in the grand fir series. Where duff accumulates and tree regeneration is dense, the potential for severe fire increases. Where large root disease centers develop, crown fire is unlikely but severe surface fire is possible. Postfire tree regeneration depends on fire severity, seed source, and site conditions. Succession may be entirely dominated by Douglas-fir (Pathway 2.4).

Pathway 2.3. Early Succession Dominated by Lodgepole Pine—On cold sites (PSME/VACA, PSME/VAGL, and PSME/CARU habitat types), lodgepole pine may dominate for about a century after fire, followed by Douglas-fir (Cooper and others 1991). This successional pathway has been described for the PSME/VAGL habitat type in western Montana (Arno and others 1985). Potential floristic composition of PSME/CARU stands in this pathway was described for central Idaho by Steele and Geier-Hayes (1993).

Pathway 2.4. Succession Dominated by Douglas-fir—Where ponderosa pine and western larch have been harvested or their regeneration impeded (often a result of fire exclusion), Douglas-fir dominates the overstory throughout stand development. If large root disease centers occur, the stand initiation stage may be cyclic, failing to lead to further development.

Fire Management Considerations

Lightning produces frequent ignitions in Fire Group Two stands. Even in wilderness areas, however, the area burned by prescribed natural fires is likely to be considerably less than that burned in presettlement times, and fires are likely to be more severe (Barrett 1988; Brown and others 1994). Habeck (1990) pointed out that natural areas lose their value if natural processes are altered or removed. Prescribed burning can be used in wilderness areas or near wilderness boundaries to reduce the risk of fire spread outside wilderness during prescribed natural fires (Arno and Brown 1989; Brown 1992-1993).

Brown and others (1994) compared the extent of fire in the Selway-Bitterroot Wilderness during presettlement times with the extent of fire in recent years (since 1979, when prescribed natural fire was first included as a management option for most of the area in the Selway-Bitterroot). In their ponderosa pine fire regime type, which includes many stands in the PSME/PHMA and ABGR/PHMA habitat types, the

average area burned per year in presettlement times was probably (95 percent confidence interval) between 5,965 and 9,671 acres; the 95 percent confidence interval for recent years was much less, 193 to 4,127 acres. Of the area burned in recent years, 26 percent has been in stand replacement fire; there was very little evidence of stand replacement fire in the ponderosa pine fire regime type during presettlement times. In wilderness areas where the current time between fires far exceeds the presettlement average fire-free interval, management-ignited prescribed burns can be used to meet wilderness goals (Brown 1992-1993).

Between 1979 and 1987, 60 percent of natural ignitions were allowed to burn in the Moose Creek Ranger District of the Selway-Bitterroot Wilderness; much of the burning occurred in ponderosa pine stands (Saveland and Bunting 1988). Many ponderosa pine stands have burned two or more times. Most fires started on or near ridgetops, then backed downslope. Fires tended to slow or even stop when they entered recently burned areas. The initial backing spread pattern and the variable fuel mosaic, combined with diurnal changes in burning conditions, produced generally low-severity fires. Most prescribed natural fires burned less than 10 acres, although multiple ignitions within a drainage occasionally consolidated into a single large fire. Little postburn soil movement was observed, apparently because foliage that fell from scorched trees protected the soil from raindrop impact.

Fire can be used in Group Two stands to enhance forage, maintain open forest structure, reduce fuel continuity, and enhance tree regeneration. In the Boise National Forest of central Idaho and the Malheur National Forest of eastern Oregon, combinations of prescribed fire with thinning or understory removal have been recommended for restoring ponderosa pine and reducing spruce budworm (Morelan and others 1994; Powell 1994). Several studies describe prescription windows for burning in Group Two stands (table 21). Management-ignited burns have been conducted in both spring and fall. Duff moisture can be used to predict and control fire severity (Simmerman and others 1991).

Fire generally enhances forage production and quality on Group Two sites (Armour and others 1984; Saveland and Bunting 1988; Weaver 1968). Increased productivity results from reduced competition, reduced litter, and increased nutrient availability (Saveland and Bunting 1988). In the Blue Mountains, OR, ponderosa pine stands with 50 percent forest cover produced more than five times as much forage (mainly *Calamagrostis rubescens* and *Carex geyeri*) as closed-canopy stands (Hall 1980). In general, open stands contained more palatable species, including *Ceanothus velutinus,* than closed stands. *Calamagrostis rubescens* palatability was enhanced where more than half of the duff was consumed by fire.

Fire effects on understory vegetation in Fire Group Two are related to the condition of the site before burning. Research in western Montana indicates that revegetation by herbaceous species is rapid even on severe burns if *Calamagrostis rubescens* cover was substantial before the burn (Crane and others 1983). However, data from prescribed burns in PSME/PHMA stands on the Coeur d'Alene Reservation, ID, suggest that cover of grassy species may be reduced for at least 3 years by severe fire (Armour and others 1984). Where *Pteridium aquilinum* is well established, burning may enhance its growth and thus inhibit other understory species and tree regeneration (Cooper and

Table 21—Ranges of conditions for prescribed underburning in Fire Group Two stands. Wind speed measured at midflame height.

Cover	Average windspeed	Cloud cover	Temperature	Relative humidity	Fuel moisture 1 hr	10 hr	100 hr	duff	Time of year
	mi/hr	*Percent*	*°F*	*Percent*					
Ponderosa pine with Douglas-fir, w. larch[a]	6-10	<30	65-75	25-35	6-14	8-15	15-30	—	Fall
Ponderosa pine with Douglas-fir, grand fir[a]	3-8	<30	60-70	25-35	6-14	8-15	15-30	—	Spring, fall
Ungrazed PSME/PHMA[b]	0-6	<70	56-74	27-35	—	9-15	—	—	Fall
Grazed PSME/PHMA[b]	0-3	<30	56-57	30-40	—	17-19	—	—	Fall
Ponderosa pine with Douglas-fir[c]: "moist"	2-6	—	64-66	31-33	—	10	—	91	Spring
"dry"	0-5	—	63-72	22-39	—	11	—	35	Spring, fall

[a]Ranges of conditions preferred by experienced burners for underburns in these cover types (Kilgore and Curtis 1987).
[b]Ranges of conditions used for underburns in PSME/PHMA habitat type in University of Idaho Experimental Forest (Zimmerman 1979).
[c]Ranges of conditions used for underburns of partially cut stands in moist Douglas-fir and dry grand fir habitat types in the Payette National Forest, central Idaho (Simmerman and others 1991).

others 1991). Heavy grazing interacts with fire exclusion to reduce forage and the potential for frequent, low-severity fire, and increase regeneration of Douglas-fir and grand fir, which increases the potential for severe fire (Rummel 1951; Zimmerman and Neuenschwander 1984).

In early successional stages, Group Two stands produce high volumes of winter forage for elk and deer, and berries for bears, grouse, and other small animals (Arno and others 1985; Steele and Geier-Hayes 1989, 1993). Severe fires every 30 to 60 years maintain shrub cover (Barrett and Arno 1991). Spring burns to maintain seral shrubfields on PSME/PHMA stands in western Montana favored *Ceanothus velutinus* and *Physocarpus malvaceus* over other shrub species (Noste 1982). Severe burning produces a flush of *Ceanothus velutinus,* if seed is present in the soil, but decreases *Vaccinium globulare* and *Xerophyllum tenax*. On sites exposed to intense sun and wind, any form of canopy removal decreases *Vaccinium globulare*, apparently because snowpack is not sufficient to protect stems from lethal winter temperatures (Arno and others 1985). Natural reforestation in severely reburned areas is extremely slow. For more discussion, see "Persistent Seral Shrubfields."

Where seral tree species dominate the canopy in Group Two stands, underburning can be used to decrease fuels, maintain open stand structure, enhance tree growth, and reduce the proportion of Douglas-fir in the understory (Fiedler 1982; Morelan and others 1994; Saveland and Bunting 1988; Steele and others 1986; Zimmerman and Neuenschwander 1984). Where dense regeneration occurs, mechanical thinning or partial or group cutting is usually recommended in combination with underburning. Severe fire behavior should be avoided to protect the soil's reservoir of decaying wood (Harvey 1982). Graham and others (1994) recommended leaving 7 to 14 tons per acre of woody debris larger than 3 inches in diameter after harvesting in ABGR/SPBE and PSME/PHMA stands. Low-severity fire apparently does not increase ponderosa pine susceptibility to bark beetle (Safay 1981). Tree condition prior to underburning, however, influences treatment success. In the Payette National Forest, central Idaho, stands in moist Douglas-fir and dry grand fir habitat types were thinned to 40 square feet of basal area per acre and then underburned (Simmerman and others 1991). Mortality of small ponderosa pine (less than 10 inches d.b.h.) exceeded that of small Douglas-fir, perhaps because ponderosa pine were highly stressed from growing conditions in the dense, shaded understory.

Restoration of seral species on Group Two sites without fire is difficult. Herbicides and intense scarification may be applicable in some situations, but both of these techniques can cause environmental degradation (pollution, soil compaction, erosion, and invasion of weedy species) (Arno and Ottmar 1994). Underburning is a unique management tool because of its ability to kill small, shade-tolerant trees and produce short-term increases in available nitrogen. Arno (1988) described a strategy for managing thickets of Douglas-fir on the Lolo National Forest, MT: First, thinning can be used to reduce pathogens and enable trees to grow to commercial size. When this growth is achieved, the trees can be harvested and the site burned and planted to ponderosa pine, western larch, and lodgepole pine. Future management can then include partial cutting and understory burning to favor seral species. Where large quantities of woody fuels have accumulated or ladder fuels are plentiful, mechanical thinning and fuel removal can be used in conjunction with a series of low-severity prescribed fires to perpetuate old-growth ponderosa pine and regenerate seral species (Arno and others 1995; Mutch and others 1993).

Fire can be used to enhance tree regeneration on Group Two sites because it removes duff and reduces competition from grassy species for 1 to 2 years (Foiles and Curtis 1973; Steele and Geier-Hayes 1989). Requirements for exposed mineral soil depend on site conditions. In central Idaho, regeneration is optimum in PSME/PHMA stands where 50 to 60 percent of mineral soil is exposed; in PSME/CARU stands, 80 to 90 percent exposure is optimum. Severe fire behavior, however, can produce dense *Ceanothus* or *Salix* cover that outcompetes tree seedlings (Steele and Geier-Hayes 1993). In the Priest River Experimental Forest, where Group Two habitat types are intermixed with Group Seven and Eight habitat types, ponderosa pine and western larch germinated more successfully on burned than unburned seedbeds under partial cuts. Dry burns (0-1 inch fuel moisture 11 percent, duff moisture 35-41 percent) produced twice as many seedlings as moist burns (0-1 inch fuel moisture 10-14 percent, duff moisture 88-91 percent) (Simmerman and others 1991). In central Idaho, seedlings establish more successfully in fire-treated than scarified PSME/PHMA and PSME/CARU stands because fire stimulates resprouting of perennial herbs and shrubs rather than germination of the early seral species that pocket gophers prefer (Steele and Geier-Hayes 1989, 1993).

On dry sites in western Montana habitat types similar to those of Fire Group Two, shelter is essential for establishment of tree seedlings (Arno and others 1985; Fiedler 1982; Jones 1995). In central Idaho, most ponderosa pine seedlings in the PSME/PHMA and PSME/CARU habitat types occur under 34 to 66 percent shrub cover, and many occur under a partial overstory (Steele and Geier-Hayes 1989, 1993). Ponderosa pines grow above the shrub layer in 10 to 20 years. In central Idaho, Steele and Geier-Hayes (1989) found that natural regeneration of Douglas-fir was impeded in PSME/PHMA stands lacking tree cover; Jones (1995) found that Douglas-fir seedlings occurred

mainly where shade was provided by shrubs, especially snowbrush, or the forest edge. In harvested ABGR/SPBE stands in central Idaho, western larch and Douglas-fir regenerated most successfully under 25 to 50 percent canopy cover (Geier-Hayes 1994); additional shelter from understory vegetation and debris favored establishment of Douglas-fir but not western larch. Several authors have discussed the difficulty of establishing tree regeneration on steep, south- or west-facing slopes (for example, Ferguson and Carlson 1991; Fiedler 1982). On moist sites, natural regeneration after canopy removal is usually dominated by Douglas-fir. If not overtopped by shrubs, western larch also thrives where mineral soil has been exposed (Ferguson and Carlson 1991).

Growth of seedlings on burned sites in Fire Group Two often exceeds that on unburned sites. In the PSME/CARU habitat type in central Idaho, site preparation by burning enhances growth of tree regeneration substantially (Steele and Geier-Hayes 1993). In western Montana, ponderosa pine establishment was studied in underburned PSME/CARU stands (Harrington 1977; Harrington and Kelsey 1979). Fires were conducted in the fall, when litter moisture ranged from 6 to 9 percent and duff moisture ranged from 11 to 19 percent; litter and duff depth reduction ranged from 65 to 91 percent. Ponderosa pine seedlings on burned sites were larger and more vigorous than those in any other treatment, probably because burning enriched soil concentrations of ammonium-nitrogen, phosphates, and potassium.

Fire Group Three: Habitat and Community Types Dominated by Persistent Lodgepole Pine

Abies lasiocarpa/Vaccinium caespitosum h.t. (ABLA/VACA), subalpine fir/dwarf huckleberry
Abies lasiocarpa/Vaccinium scoparium h.t. (ABLA/VASC), subalpine fir/grouse whortleberry
Pinus contorta/Vaccinium caespitosum c.t. (PICO/VACA), lodgepole pine/dwarf huckleberry
Pinus contorta/Vaccinium scoparium h.t. PICO/VASC), lodgepole pine/grouse whortleberry
Pinus contorta/Xerophyllum tenax c.t. (PICO/XETE), lodgepole pine/beargrass

Vegetation

Fire Group Three consists of the northern Idaho habitat and community types dominated by persistent or climax lodgepole pine. Seral lodgepole pine is described in the introductory section and within other fire groups, especially Group Four. Persistent lodgepole pine communities, described here, contain only scattered subalpine fir, "apparently not in sufficient quantities nor vigor to replace lodgepole pine..." (Pfister and Daubenmire 1975). Group Three habitat and community types are not widespread in northern Idaho; most stands occur in the Nez Perce and Clearwater National Forests. Group Three stands are usually in the subalpine zone at elevations above 5,000 feet, on relatively severe sites (frost pockets or windy areas near ridges) or on poor soils (coarse-textured, very thin, or without ash layer). Some occur on sites with fluctuating water tables, so soils are saturated in spring and very dry in late summer.

Vegetation is not diverse on Group Three sites. The tree layer is dominated by lodgepole pine; mature stands are open, and lodgepole pine can reproduce in small clearings (fig. 16). Subalpine fir, Douglas-fir, grand fir, and Engelmann spruce also occur.

Vaccinium caespitosum, *Vaccinium globulare*, and *Vaccinium scoparium* are the only important shrubs on Group Three sites. Cover of *Vaccinium scoparium* is often greater than 50 percent. On most sites, *Xerophyllum tenax* is the only forb that provides more than a trace of cover. Other forbs include *Arnica*, *Chimaphila umbellata*, *Lupinus* species, and *Luzula hitchcockii*. Four grassy species occur, although they do not provide dense cover: *Calamagrostis rubescens*, *Carex concinnoides*, *Carex geyeri*, and *Carex rossii*.

Fuels

Group Three stands have relatively low productivity, which is often reflected in light fuel loadings. Fuels are discontinuous, both horizontally and vertically.

Figure 16—Vegetation and fuels in Fire Group Three. ABLA/VACA stand near Elk Summit, Powell Ranger District, Clearwater National Forest. Site is nearly level, dominated by open stand of lodgepole pine, with occasional subalpine fir in understory.

Litter and duff are shallow; downed woody fuel loadings depend on the quantity of small branches from self-pruning, level of dwarf mistletoe infestation, and extent of overstory mortality. In two ABLA/VACA stands in the Lolo National Forest, MT, Fischer (1981c) found average duff depths less than 1.5 inches. Dead and downed woody fuel loadings were 3.5 and 7.1 tons per acre, with no more than 1.5 tons per acre in fuels less than 1 inch in diameter. Terrain is usually gentle in Group Three stands and canopies are open. Where fuels are light or discontinuous, rapid fire spread and uniform burning can occur only during severe climatic conditions.

When patches of dense lodgepole pine have intermingled crowns and low branches extending into surface fuels, fire hazard can be high. Mistletoe infestation increases the potential for torching and crowning. Heavy loadings of woody fuels, likely in stands infested by mountain pine beetle, increase the potential for severe fire.

Role of Fire

Cooper and others (1991) listed the factors influencing establishment of Fire Group Three stands in northern Idaho. In order of importance, they are:

1. Frequent, widespread, stand-replacing fires that have eliminated seed from competing species.
2. Removal of competing species by low-severity fire.
3. Dense lodgepole pine reproduction that excludes other species.
4. Site conditions that have been unsuitable for establishment of other conifers.

Group Three stands in northern Idaho typically have even-age overstories and retain charcoal in the soil, indicating that they originated after fire (Cooper and others 1991). Some even-age stands contain dominant and very suppressed trees of the same age, with virtually no additional regeneration. Canopy removal over large areas is not essential for lodgepole pine reproduction, however. Mature trees in Group Three stands produce primarily open cones (Cooper and others 1991), so seed is plentiful to regenerate in openings created by lightning, fire, mountain pine beetle mortality, snow breakage, and windthrow.

No fire history studies specifically address the Group Three habitat types in northern Idaho. Many stands in this fire group are interspersed with Group Four stands in the Elk Summit area of the Nez Perce National Forest, where Barrett (1993) found mean intervals between stand-replacing fires of 195 years or more, and mean intervals between nonlethal fires of 41 years. In western Montana, most ABLA/VASC stands older than 150 years showed evidence of one to three low-severity fires after establishment (Pfister and others 1977). The result was a mosaic of patches of different sizes and ages rather than the large, single-age stands typical where lodgepole pine is seral.

In Fire Group Three, mountain pine beetle infests and kills most pines as they reach large size classes; the openings thus created are then seeded by lodgepole pine (Cole and Amman 1980; Wellner 1978). This pattern is repeated as other pines become large enough, and develop phloem thick enough, to support large beetle populations (Amman 1977). Occasional pine beetle epidemics occur in the habitat types of Fire Group Three (Pfister and others 1977), but they are not as common as in more productive habitat types dominated by lodgepole pine (Cole and Amman 1980).

Moderate rates of dwarf mistletoe infection occur in persistent and climax lodgepole pine stands, locally increasing surface fuels and vertical fuel continuity. Mistletoe may limit mortality caused by pine beetles because it decreases phloem thickness (Amman 1977). Pine beetles facilitate mistletoe infestation, since the parasite spreads from mature trees to regeneration in openings created by beetle-caused mortality (Wellner 1978).

The effects of fire exclusion are difficult to quantify in long-interval fire regimes, including those typical of Fire Group Three. In the extensive lodgepole pine forests of Yellowstone National Park, large or severe fire may be more common now than in presettlement times because low-severity fires have not maintained variation in stand structure and fuel discontinuity over the landscape; however, such changes have not been demonstrated quantitatively (Romme 1982).

Forest Succession

Lodgepole pine is often the only tree species present on Group Three sites, and understory diversity is low; where other tree species occur, they are not vigorous enough to replace lodgepole pine in succession. Consequently, species composition changes little throughout stand development. Stand structure changes and is significantly influenced by the fire regime. Succession has not been described for Group Three stands in northern Idaho. The following description is based mainly on autecological properties of lodgepole pine.

After severe fire, herbs and shrubs revegetate the site from surviving roots and stems (fig. 17 A). (Subsequent references in this section are to fig. 17.) The rate of postfire tree regeneration (B) depends on the severity and uniformity of fire behavior, the relative availability of closed and open cones, and postfire moisture conditions. Regeneration from open cones is slower than when most seed is from closed cones, but it may be more dependable because seed is available most years. Regeneration patterns depend on burning patterns. Regeneration is widely distributed if fire behavior

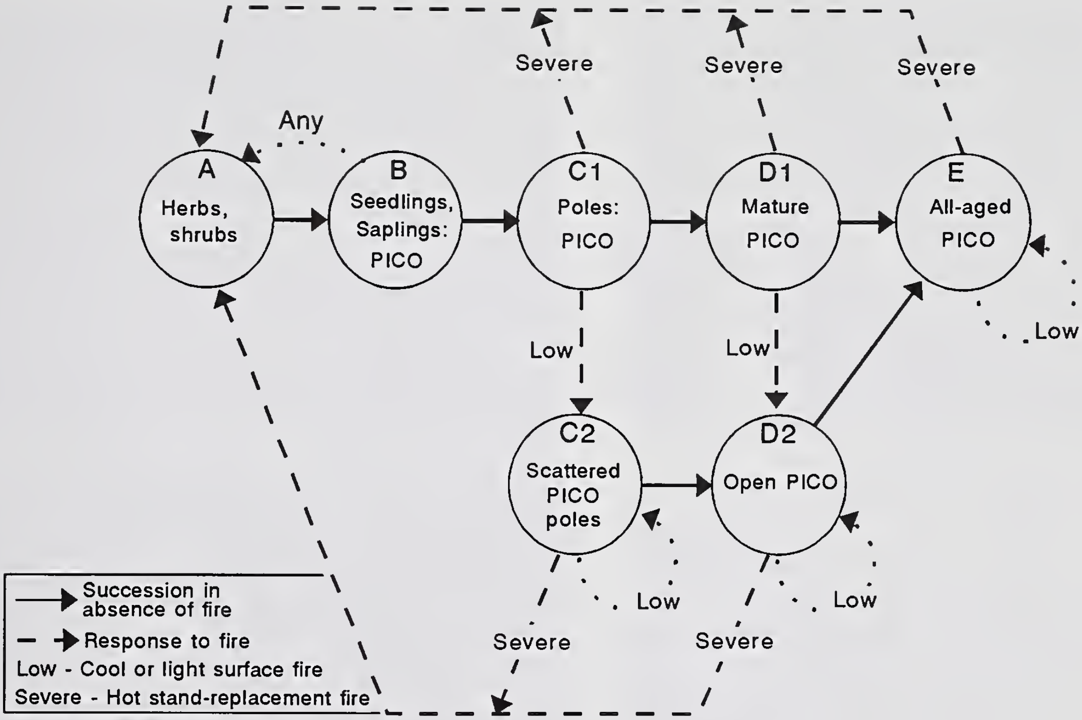

Figure 17—Hypothetical fire-related succession for Fire Group Three stands, characterized by almost-pure lodgepole pine forest. Occasional regeneration of subalpine fir, Douglas-fir, grand fir, and Engelmann spruce also occurs.

was relatively uniform and seed plentiful; it is sparse and slow in severely burned patches and clumped in even-age groups where fire was of mixed severity.

Pole stands (C1) are open, with occasional dense patches. Stand-replacement fires are possible during droughts with high winds. Patchy or very low-severity fire thins the stand (C2), favoring lodgepole pine regeneration from open cones. (Lodgepole pines can produce seed when they are as young as 5 years.)

Over time, mature forest develops (D1, E). Its structure depends on disturbance history and site conditions. Low-severity fires maintain an open canopy (D2), as do other agents of mortality. Where intense outbreaks of mountain pine beetle occur, they contribute to heavy fuels and increase potential fire severity.

Fire Management Considerations

In presettlement times, Group Three stands burned infrequently, with varying severities. Effects of fire exclusion are subtle and slow to develop, but probably include increased infestation by dwarf mistletoe and increased incidence of mountain pine beetle irruption. Most Group Three stands are small and isolated, so they are likely to be strongly affected by changes in the fire regime in neighboring stands—mostly dry subalpine habitat types (Fire Group Four).

Historic fires may have contributed to the establishment or expansion of Group Three stands by increasing erosion. Modern-day fires also degrade marginal soils and can thus change an area from a more productive habitat type (Fire Group Four or Five) to a Group Three habitat type. Increased runoff from snowmelt would probably accompany the change. To prevent such changes, fire management plans would need to exclude fire from sites with coarse, ash-poor soils when duff and downed woody fuels are excessively dry. Management activities that reduce fuel continuity and increase landscape diversity reduce the potential for site degradation from severe fire; they can also expand opportunities for prescribed natural fire in wilderness areas (Brown 1992-1993). Seasonally saturated soils in some Group Three stands are vulnerable to mechanical disturbance during spring and early summer.

Elk, mule deer, and moose use mature Fire Group Three stands for cover and for summer and fall forage. *Vaccinium* fruits are used by blue grouse. The Fire Group Three habitat types have little value for livestock.

Prescribed fire is used on Group Three sites for hazard reduction and site preparation in conjunction with tree harvesting. Tree regeneration and growth are slow. The average height of 100 year old trees on PICO/VASC sites in northern Idaho was 60 feet; average d.b.h. was less than 12 inches (Cooper and others 1991). Regeneration with species other than lodgepole pine is likely to fail on these dry, frosty sites.

Opportunities to use understory fire in Group Three stands are limited because lodgepole pine has low resistance to fire; when fuels are moist enough to protect mature trees, surface fires burn patchily or are difficult to sustain.

Fire Group Four: Dry, Lower Subalpine Habitat Types

Abies lasiocarpa/Calamagrostis rubescens h.t. (ABLA/CARU), subalpine fir/pinegrass+

Abies lasiocarpa/Vaccinium globulare h.t. (ABLA/VAGL), subalpine fir/blue huckleberry+

Abies lasiocarpa/Xerophyllum tenax h.t. - *Coptis occidentalis* phase (ABLA/XETE-COOC), subalpine fir/beargrass - western goldthread phase+

Abies lasiocarpa/Xerophyllum tenax h.t. - *Luzula hitchcockii* phase (ABLA/XETE-LUHI), subalpine fir/beargrass - smooth woodrush phase+

Abies lasiocarpa/Xerophyllum tenax h.t. - *Vaccinium globulare* phase (ABLA/XETE-VAGL), subalpine fir/beargrass - blue huckleberry phase+

Abies lasiocarpa/Xerophyllum tenax h.t. - *Vaccinium scoparium* phase (ABLA/XETE-VASC), subalpine fir/beargrass - grouse whortleberry phase+

Tsuga menziesia/Xerophyllum tenax h.t. - *Luzula hitchcockii* phase (TSME/XETE-LUHI), mountain hemlock/beargrass - smooth woodrush phase

Tsuga mertensiana/Xerophyllum tenax h.t. - *Vaccinium globulare* phase (TSME/XETE-VAGL), mountain hemlock/beargrass - blue huckleberry phase+

Tsuga mertensiana/Xerophyllum tenax h.t. - *Vaccinium scoparium* phase (TSME/XETE-VASC), mountain hemlock/beargrass - grouse whortleberry phase+

+ May be dominated in early succession by lodgepole pine.

Vegetation

The subalpine habitat types of Fire Group Four can be found in northern Idaho at elevations from 3,900 to 7,600 feet. Group Four sites are dry, often because of position; they usually occur on south- to west-facing slopes or near ridgetops. Canopy cover is partially open even in many mature stands (fig. 18, table 22). Subalpine fir and mountain hemlock are the climax tree species. Early succession can be dominated by lodgepole pine or by a mixture of lodgepole pine, Engelmann spruce, Douglas-fir, and climax species. Grand fir, western larch, western white pine, and quaking aspen are less prevalent seral species (Cooper and others 1991; Simpson 1990). Whitebark pine intergrades with lodgepole pine at high elevations (discussed in Fire Group Six). Most habitat types can be dominated by lodgepole pine in early succession. But knowledge of fire regime, previous species composition, and conditions in neighboring stands are important for predicting succession.

Vaccinium globulare (intergrading with *Vaccinium membranaceum*) and *Vaccinium scoparium* are widespread on Group Four sites. Other important shrubs include *Alnus sinuata*, *Ceanothus velutinus*, *Lonicera utahensis*, *Ribes* species, *Salix scouleriana*, *Sambucus racemosa*, *Sorbus scopulina*, and *Spiraea betulifolia*. In the herb layer, *Xerophyllum tenax* is a widespread dominant. Other common forbs include *Anemone piperi*, *Arnica latifolia*, *Chimaphila umbellata*, *Coptis occidentalis*, *Goodyera oblongifolia*, *Luzula hitchcockii*, *Pyrola secunda*, and *Viola orbiculata*. *Anaphalis margaritacea*, *Antennaria* species, *Epilobium angustifolium*, and *Lupinus argenteus* are important early seral forbs. *Bromus vulgaris*, *Calamagrostis rubescens*, *Carex geyeri*, and *Carex rossii* are present on many sites; grassy species can form a dense sward under a partially closed canopy.

The transition from dry to moist forest in lower subalpine stands can be abrupt or very gradual, as can the transition from lower to upper subalpine vegetation. Where the habitat types of Fire Group Four intergrade with those of Groups Five and Six, their fire regimes and successional patterns are intermediate between those described here.

Fuels

Fuel loadings and continuity vary in Group Four stands, depending mainly on species composition, fire history, natural thinning, snow breakage, and levels of dwarf mistletoe and mountain pine beetle. Brown and Bradshaw (1994) described fuel models for Group Four lodgepole pine stands in the Selway-Bitterroot Wilderness. They used the following loadings (tons per acre) for surface fuels: litter, 0.6; duff, 10.0; herbs, 0.6; shrubs, 0.3; tree regeneration, 1.1.

Dead and downed woody fuels in Fire Group Four are often dominated by the large size classes. In three northern Idaho stands, dead and downed woody fuels less than 1 inch in diameter represented only 3 to 10 percent of total woody fuel loading (table 22). Fuels were light in Stand 4A, a stand of open, pole-size lodgepole pines; they were heavier in two stands containing medium-size trees (Stands 4D and 4E).

Figure 18—Vegetation and fuels in Fire Group Four. A. Stand 4A, partially open stand on south-facing slope, Nez Perce National Forest, south of Elk City. Dominants are pole-size lodgepole pine. Photo by Jim Mital. B. Stand 4B, partially open stand in TSME/XETE-VAGL habitat type on ridge near Moon Pass, Avery District, St. Joe National Forest. Burned in 1910 fire. Mountain hemlock dominates ridge and northwest-facing slope; lodgepole pine and western white pine dominate south-facing slope. C. Stand 4C, open forest on south-facing slope in ABLA/XETE-LUHI habitat type, near Gisborne Mountain, Priest River Experimental Forest. Overstory is a dominated by subalpine fir and Engelmann spruce, with a few lodgepole pine.

Table 22—Stand characteristics and fuel loadings in some Fire Group Four stands. Fuel loadings are in tons/acre. Stand 4A is shown in figure 18. (Data were provided by Jim Mital and are on file at Intermountain Fire Sciences Laboratory, Missoula, MT.)

						Dead and down load by size class (inches)					Total
Stand No.	Habitat type-phase	Age	Tree spp.	Canopy cover	Litter, duff depth	0-¼	¼-1	1-3	3+ sound	3+ rotten	dead and down load
		Years		*Percent*	*Inches*	*Tons per acre*					
4A[a]	ABLA/XETE-VASC	86	PICO	50	0.4	0.0	0.1	0.0	0.0	2.6	2.7
			PSME	10							
4D	ABLA/XETE-COOC	92	PSME	30	1.1	0.1	1.0	2.8	3.7	3.1	10.7
			LAOC	20							
			PICO	10							
			PIEN	10							
4E	ABLA/CARU	110	PICO	40	1.7	0.0	0.4	1.8	2.5	7.5	12.2
			PSME	10							
			ABLA	10							

[a]Refers to stand number in text.

Total dead and downed woody fuels in Group Four stands in the Selway-Bitterroot Wilderness averaged 25.5 tons per acre (Walker 1973). In the habitat types of Fire Group Four in western Montana, Fischer (1981c) found total woody fuel loadings ranging from 1.2 to 77.3 tons per acre. The latter occurred in a stand containing 200 year old Engelmann spruce, with younger subalpine fir and lodgepole pine. The maximum woody fuel loading in the lodgepole pine cover type was 32.0 tons per acre. Duff depths on most sites were less than 3 inches.

Spruce and subalpine fir regeneration enhance fuel continuity in Fire Group Four, increasing the potential for rapid fire spread, torching, and crowning. Dwarf mistletoe and lichen-draped trees also increase the potential for vertical fire spread (Agee 1993). Heavy dead and downed woody fuels, likely to occur after stand-replacing fire and after mountain pine beetle irruptions, increase the potential for severe fire. (See "Seral Lodgepole Pine in Northern Idaho.")

In subalpine forests of the Rocky Mountains and Pacific Northwest, fire severity is limited in most years by fuel moisture. With sustained drying, however, the potential for crown fire increases. The 1988 fires in Yellowstone National Park were weather-driven and burned through stands in all successional stages (Agee 1993).

Role of Fire

The most obvious role of fire in presettlement forests of Fire Group Four was to kill overstory trees and generate a new, even-age forest. Stand-replacing fires occurred in Group Four stands at average intervals ranging from 52 to 200 years or more (table 23). Stand-replacing fire occurred less frequently at high than low elevations within this fire group because of slower tree growth and less continuous fuels at high elevations (Barrett 1982; Green 1994).

Lightning-caused fires in northern Idaho occur most frequently at elevations from 3,450 to 5,400 feet, a range that includes many lower subalpine forests (Fowler and Asleson 1984). Lightning ignitions are most frequent on the upper one-third of slopes, on aspects perpendicular to prevailing storm tracks. Most stand-replacing fires in Group Four originated at relatively low elevations, often in the lodgepole pine cover type; fires originating at high elevations tended to be small and burn with low severity (Barrett 1982). According to Heinselman (1981), the fire regime in most subalpine forests consists of infrequent crown fire and occasional severe surface fire. Mutch (1992) reported that fires in this fire regime often cover 5,000 to 100,000 acres.

Nonlethal fire was common in Fire Group Four during presettlement times. Intervals between nonlethal fires

Table 23—Presettlement fire regimes for Fire Group Four habitat types in northern Idaho. Locations of studies are shown in figure 1. Fire interval range lists minimum and maximum individual intervals from the study area. Mean fire interval and standard deviation (s.d.) are computed from stand mean fire intervals for the study area.

Location, habitat types, cover	Fire severity	Years: Fire interval range	Years: Mean fire interval	S.d.	Number of stands
Priest River Basin[a]:	Low to moderate		>150		
—ABLA series, broken terrain					
Cook Mtn., Clearwater National Forest[b]:	Low to moderate, crowning mainly in lodgepole pine	9 to 117	35	10	10
—ABLA & TSME series					
White Sands area, Clearwater National Forest[c]:					
ABLA/XETE					
—spruce-fir cover	Stand replacing	164+ to 241+	217+		6
—lodgepole pine cover	Stand replacing	117 to 386	195+		24
	Nonlethal	20 to 67	41	11	10
Selway Ranger District, Nez Perce National Forest[d]:					
ABLA/XETE					
—lodgepole pine cover	Stand replacing		52		3
Selway-Bitterroot Wilderness[e]:					
—ABLA/XETE,/LIBO, with lodgepole pine	Stand replacing		117		16
	Nonlethal		43	13	5

[a]Arno and Davis (1980). Includes stands in Fire Groups Four and Five.
[b]Barrett (1982).
[c]Barrett (1993). "+" indicates fire interval was incomplete at time of study but its inclusion did not shorten mean.
[d]Green (1994).
[e]Barrett and Arno (1991), Brown and others (1994, 1995).

averaged 30 to 50 years (table 23). Nonlethal fire was most common in lodgepole pine, but open stands containing fire-scarred subalpine fir and mountain hemlock can also be found (fig. 19). In the Cook Mountain area of the Clearwater National Forest, several subalpine firs and mountain hemlocks had two or three fire scars (Barrett 1982). About 40 percent of ABLA/XETE-VAGL stands and two-thirds of ABLA/XETE-VASC in western Montana experienced nonlethal fire after establishment (Arno 1976; Barrett and others 1991; Fiedler 1982). Low-severity fires in dry subalpine stands can occur under many circumstances: during mild summers or mild burning periods, along the edges of large burns, and on sheltered or moist locations within severe burns (Brown 1975; Green 1994).

Figure 19—Fire-scarred subalpine fir in ABLA/XETE-VAGL stand on a gentle, south-facing slope in the Clearwater Ranger District, Nez Perce National Forest. Stand structure was open, dominated by medium-sized lodgepole pine, most of which had fire scars.

Fire-scorched trees are more vulnerable to insect attack than uninjured trees. After the 1988 fires in Yellowstone National Park, post-burn insect infestation increased mortality for all tree species; mountain pine beetle, however, was not a principal agent of mortality (Amman and Ryan 1991).

Gentle terrain and variable topography enhance the likelihood of low-severity and mixed-severity burns in Fire Group Four. Describing fire's influence on the subalpine forests above the Selway River during the 1890's, Leiberg (1900) noted that "... the destruction has been in circumscribed patches, the bare expanses of rocks and wet meadows that break the continuity of the forest in these regions having prevented any one conflagration from spreading over a very large territory." Barrett and Arno (1991) reported that fires on gentle slopes in the same area were of mixed severity, with nonuniform spread. In dry and moist subalpine forests north of Priest Lake, Kaniksu National Forest, the extent of historic fires depended on forest continuity. Where the subalpine zone was broken by rocky outcrops and steep, moist draws, most historic fires were small. Where high-elevation forests were more continuous and more exposed to wind, fires were occasionally very large.

Arno and others (1993) illustrated the intricate vegetative mosaic formed by fires at various intervals, of varying severities, in a dry subalpine forest (mostly ABLA/XETE-VAGL and ABLA/XETE-VASC habitat types) in the Bitterroot National Forest, MT (fig. 20). Stand development in the absence of fire has altered both species composition and stand structure, favoring shade-tolerant species and mature stands (table 24).

Stand-replacing fire eliminates shade and exposes mineral soil, conditions ideal for regeneration of Douglas-fir and lodgepole pine in Group Four. Increased soil temperatures after stand-replacing fire enhance germination of lodgepole pine. A short-term increase in essential plant nutrients may occur, enhancing tree establishment and growth (Brown 1975).

Severe reburns of subalpine sites (fire-free intervals less than 30 to 50 years) produce scattered lodgepole pine or persistent shrubfields. Leiberg (1899b) commented that, in the Priest River area where lodgepole pine communities had burned two times, no reforestation was taking place. In the Clearwater National Forest, south-facing subalpine sites restocked very slowly after two to five burns between 1842 and 1919; after 62 years, tree cover averaged 35 percent (Barrett 1982).

Because severe fires in dry, lower subalpine habitat types tend to be infrequent, it is difficult to quantify changes that have occurred due to fire exclusion. General effects on dry subalpine forests in the Northern Rocky Mountains have been summarized from Arno and Brown (1991), Arno and others (1993), Barrett and others (1991), Covington and others (1994), and

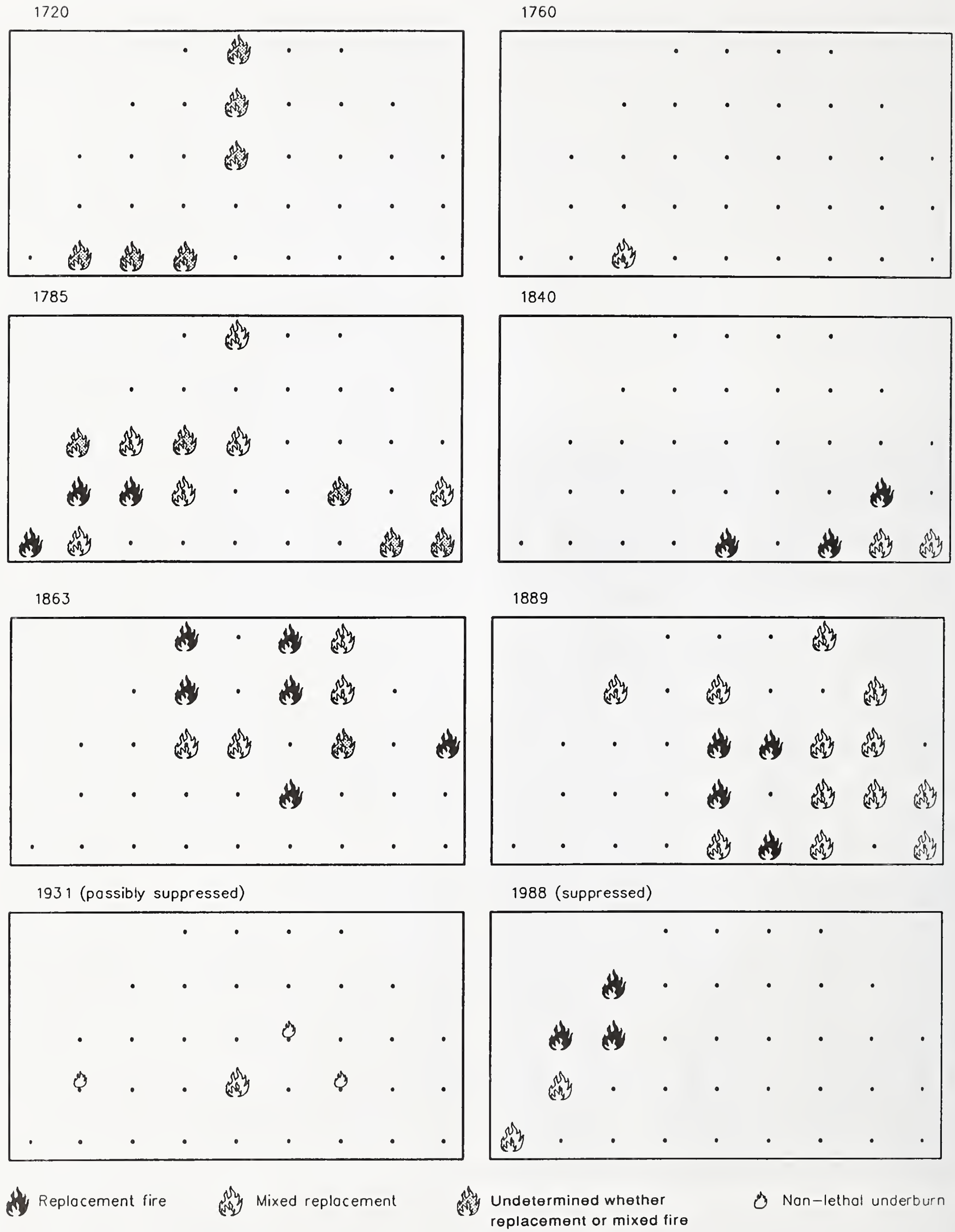

Figure 20—Variety in spatial occurrence and severity of past fires, documented for a lodgepole pine-subalpine fir forest in the Bitterroot National Forest, MT (Arno and others 1993). Dots correspond to sample plots 800 feet apart.

Table 24—Area in dry, lower subalpine forest, Bitterroot National Forest, MT, covered by various species and age classes in 1900 and 1991 (Arno and others 1993).

	Percent of area	
	1900	1991
Dominant species[a]		
Lodgepole pine	77	57
Subalpine fir	9	17
Whitebark pine	14	0
Mixed	0	26
Age class/structure[b]		
Immature	49	20
Mixed	23	37
No immature	28	43

[a]Stands were designated according to species representing at least 50 percent of basal area.
[b]Immature stands contained seedlings, saplings, or poles; mixed stands contained at least one immature seral age class as well as a mature component; stands without an immature component had not been disturbed within 110 years.

Romme (1982). Where fire has been excluded successfully over large areas, more area is in mature stands than prior to settlement by European Americans (unless harvesting has intervened). Discontinuities in stand structure and fuel arrays, created historically by low-severity fire, have been largely eliminated, so structural homogeneity has increased across the landscape. Mountain pine beetle irruptions have been extensive in mature lodgepole pine forests, locally increasing downed woody fuels. Understory trees and mistletoe have increased the vertical continuity of fuels. Because of these changes, modern-day fires may be more likely to crown or burn severely over large areas than those in presettlement times.

Forest Succession

Forest succession on the drier habitat types and phases of Fire Group Four (ABLA/XETE-VAGL, ABLA/XETE-VASC) has been described for an area including the Clearwater and Nez Perce National Forests and central Idaho (Simpson 1990), and for western Montana (Arno and others 1985). Studies describing succession in the Idaho Panhandle National Forests have not been published. Our descriptions of succession are based on the reports available, descriptions of species composition in mature stands (especially Cooper and others 1991), and references to autecological characteristics of dominant tree species.

Early postfire shrubs in moderate Group Four stands include *Ceanothus velutinus*, *Salix scouleriana*, and *Sambucus racemosa*; shrub cover is sparse on cold, dry sites (Simpson 1990). *Salix* persists in midseral stands. Substantial cover of *Vaccinium globulare* or *Vaccinium scopulorum* indicates either low-severity disturbance (Arno and others 1985) or late-seral conditions (Simpson 1990). *Calamagrostis rubescens* and *Xerophyllum tenax* are common throughout succession in the habitat types of Fire Group Four (Arno and others 1985). Simpson (1990) reported that perennials dominate the herbaceous layer in early succession: *Antennaria* species, *Carex concinnoides*, *Epilobium angustifolium*, and *Lupinus argenteus*. Herbaceous species diversity is greatest in early seral stands, but herbaceous cover is greatest in mid- to late-seral stands.

Forest succession in Group Four depends not only on habitat type but also on seed source and stand history. Severe burns can be regenerated by a mixture of Douglas-fir, lodgepole pine, and Engelmann spruce (Pathway 4.1, fig. 21), or by nearly pure lodgepole pine (Pathway 4.2, fig. 22). Severe fires occurring at intervals shorter than the lifespan of lodgepole pine (100 to 120 years in northern Idaho) should favor its increase (Cooper and others 1991); however, this pattern is not clear in fire history reports from northern Idaho (table 23). On relatively moist sites in Fire Group Four, postfire succession includes more seral species than are included in Pathway 4.1; since this pattern is common in Fire Group Five, it is described in Pathway 5.2. On moist sites and in areas where substantial shade remains after disturbance, succession is dominated by a mixture of Engelmann spruce and climax species; this pattern is described in Pathway 5.3.

The successional pathways described here are qualitative guides. Actual succession on a given site may follow a path intermediate between or diverging from those described.

Pathway 4.1. Succession Dominated by Douglas-fir, Lodgepole Pine, and Engelmann Spruce—This pathway occurs in the ABLA/XETE-COOC and ABLA/XETE-VAGL habitat types (Cooper and others 1991); it is similar to that described for ABLA/XETE-VAGL stands in western Montana (Arno and others 1985).

After severe fire, herbs and shrubs sprout vigorously (fig. 21 A). (Subsequent references in this section are to fig. 21.) Seedlings and saplings of Douglas-fir, lodgepole pine, and Engelmann spruce establish within a few years (B), with Douglas-fir most prominent at low elevations. Scattered subalpine fir may also be present. Lodgepole pine dominates the pole stage (C1) because of its rapid growth. Douglas-fir and lodgepole pine are both slightly fire-resistant as poles, so low-severity fires may leave scattered Douglas-fir and lodgepole pine (C2).

As the stand matures (D1), lodgepole pine codominates with Douglas-fir and Engelmann spruce. Subalpine fir and spruce regenerate under the partially open canopy. (Grand fir occasionally codominates with subalpine fir, although it is not included in fig. 21.) Low-severity fires produce an open stand dominated by Douglas-fir and lodgepole pine (D2). Severe fires return the site to herbs and shrubs (A). A few mature

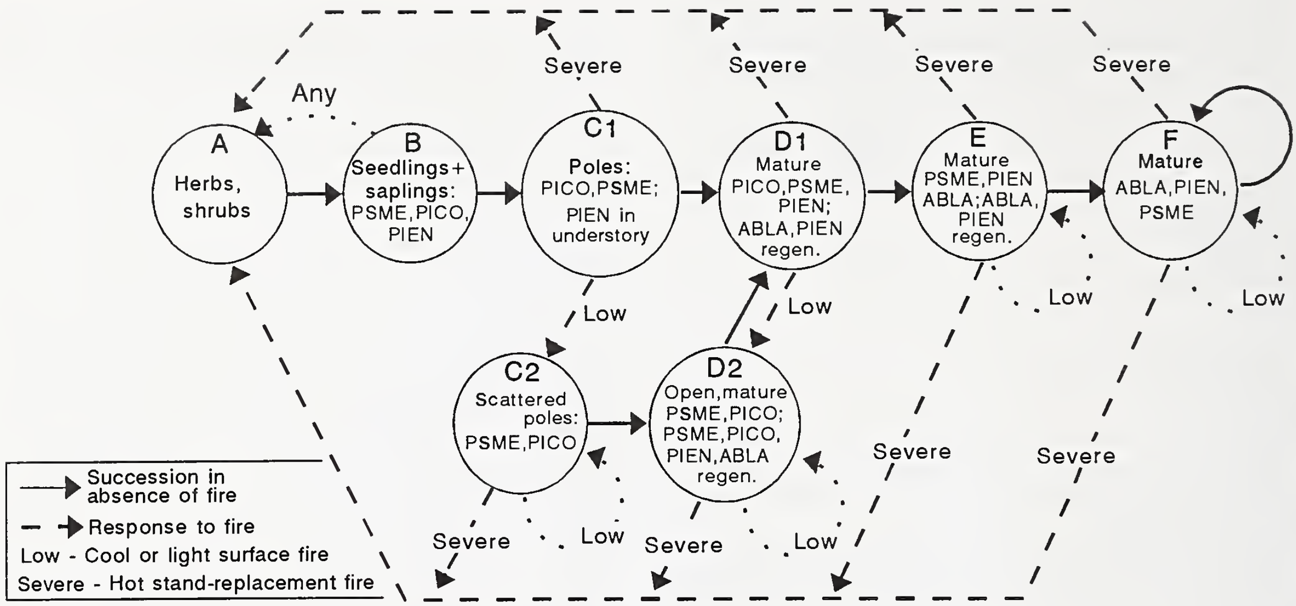

Figure 21—Pathway 4.1. Hypothetical fire-related succession for Fire Group Four stands where Douglas-fir, lodgepole pine, and Engelmann spruce are the major seral species. Succession is shown here for stands in the subalpine fir series.

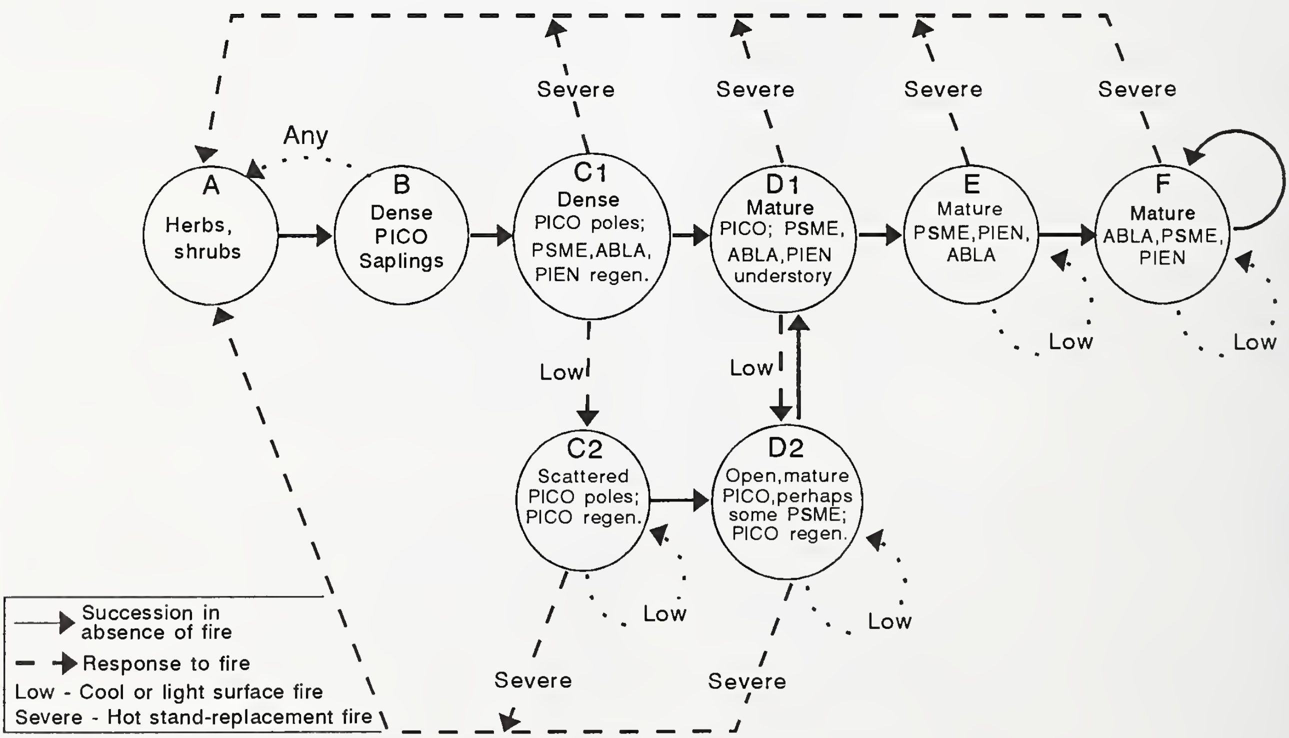

Figure 22—Pathway 4.2. Hypothetical fire-related succession for Fire Group Four stands where lodgepole pine is the major seral species. Succession is shown here for stands in the subalpine fir series.

Douglas-fir may survive severe fires, increasing the proportion of this species in regeneration.

Mountain pine beetle eliminates lodgepole pines as they reach maturity, leaving subalpine fir and Engelmann spruce to dominate with old-growth Douglas-fir (E, F). The stand can be thinned by low-severity fire, but species composition changes little. Severe fire returns the stand to herbs and shrubs (A).

Pathway 4.2. Succession Dominated by Lodgepole Pine—This pathway is common on Group Four sites in the ABLA/XETE-VAGL, -COOC, and -VASC phases (Cooper and others 1991). Arno and others (1985) described a similar pathway for ABLA/XETE-VASC stands in western Montana.

After stand-replacing fire, herbs recover rapidly (fig. 22 A). (Subsequent references in this section are to fig. 22.) Forbs are dominant for a few years, unless soil disturbance leads to dominance by grassy species. Shrubs resprout vigorously and attain dominance within 10 years.

Lodgepole pine seedlings dominate many stands in this pathway soon after fire (B), although full stocking may require 40 years or more (Arno and others 1985). When the prefire stand supported pines with serotinous cones, lodgepole pine seedlings often germinate in profusion the year after fire, with densities exceeding 10,000 per acre. Fire behavior severe enough to damage lodgepole seeds inside serotinous cones is rare. When the prefire stand supported pines bearing mainly nonserotinous cones, restocking depends mainly on seed from neighboring areas and is slower. Douglas-fir regeneration is common on relatively warm sites in this pathway; Engelmann spruce and subalpine fir also occur, but competition and shade from lodgepole seedlings suppress these species during the first postfire years.

The pole stage (C1) is dominated by lodgepole pine, which may be very dense, with low cover of herbs and shrubs in the understory. Douglas-fir, subalpine fir, and Engelmann spruce regenerate under the pines, which provide some protection from frost damage (Simpson 1990). Severe fire returns the stand to herbs and shrubs (A). Low-severity fire removes regeneration but leaves scattered lodgepole pine (C2), which reproduces from open cones in surviving poles.

Mature lodgepole pine stands (D1) vary in structure from very dense to partially open. Douglas-fir reaches the canopy and codominates with lodgepole pine. Regeneration of Engelmann spruce and subalpine fir matures. Low-severity fires remove tree regeneration along with fir and spruce (D2), creating conditions that favor regeneration by seral species.

Mature lodgepole pine are eliminated by mountain pine beetle; even-age stands are susceptible to pine beetle irruptions causing very high mortality. Douglas-fir, Engelmann spruce, and subalpine fir then dominate (E). Dead and downed fuels are heavy and dry readily under the open canopy, increasing the potential for severe fire. Low-severity fire probably favors Douglas-fir dominance, although burning in deep duff can damage the roots of this species. Openings created by low-severity fire favor regeneration by seral species.

If the stand continues without fire, subalpine fir eventually dominates (F). It is very unlikely that fire could be excluded from the area long enough to eliminate all seed from seral species.

Fire Management Considerations

Management objectives in Group Four stands include wilderness perpetuation, watershed protection, wildlife habitat maintenance, and timber production. Management-ignited fire is used to increase water yield, provide forage for wildlife species, reduce fuels, and prepare seedbeds for regeneration. Successful prescribed burning in Group Four requires that duff moisture be controlled to obtain desired tree mortality and to expose mineral soil without removing needed woody residue and duff. Moisture conditions favorable for prescribed burns often occur during late summer, when resources needed for prescribed fire are already committed to fire suppression and when fire may be difficult to control in slash and heavy natural fuels.

Fire exclusion removes an important source of landscape diversity from Group Four stands. The Selway-Bitterroot Wilderness has been managed since 1979 under a policy allowing prescribed natural fires, but the current fire regime differs substantially from that in presettlement times (Brown and others 1994). In lodgepole pine stands (mostly the Group Four habitat types), the average annual area burned in recent times is approximately 57 percent of that burned in presettlement times. The extent of both lethal and nonlethal fire has been reduced. The current interval between nonlethal fires exceeds the maximum recorded presettlement interval in approximately 80 percent of lodgepole pine stands (Brown 1992-1993).

Where duff and woody fuels are heavy, as can occur in mature stands and after mountain pine beetle irruption, smoldering persists for a long time after ignition, increasing the probability of fire spread. Conifer reproduction under the mature canopy increases vertical fuel continuity in subalpine stands, and heavy dead and downed fuels increase the potential for severe surface fire (Covington and others 1994). Intense soil heating kills the roots of shrubs and herbs, notably *Vaccinium* species, which provide important wildlife habitat. Management ignitions can be used to reduce fuel loads and increase variation in stand structure, and reduce the risk of fire spread outside wilderness during prescribed natural fires (Arno and Brown 1989).

Group Four stands on moderate sites produce abundant wildlife forage in early and mid-seral stages (Simpson 1990). Elk and deer use burns on subalpine sites for summer forage. Early seral herbs, especially *Carex* species and *Calamagrostis rubescens*, are important for bears in the spring. Bears, grouse, and other wildlife rely on seral stands for *Vaccinium* berries in summer and also on fruits of other shrubs (*Amelanchier*, *Sambucus*, and *Sorbus*) in the fall. Forage values for cattle are low in Fire Group Four; values for sheep are somewhat higher, but not as high as those for elk and deer (Simpson 1990).

Research on harvested stands in Group Four provides some insight concerning species composition in seral stands. Projections using the Prognosis Model indicate that, 10 years after clearcutting without site preparation, regeneration on dry subalpine stands at 5,500 feet elevation is dominated by subalpine fir and Douglas-fir, with western larch and grand fir also common (Ferguson and Carlson 1993). In ABLA/XETE stands in Idaho, lodgepole pine regenerated less successfully after harvesting (with or without site preparation) than after wildfire (McCaughey and others 1991; Simpson 1990). In moderate ABLA/XETE-VAGL stands in western Montana, lodgepole pine regenerated promptly after wildfires, but only on about 50 percent of clearcuts (Arno and others 1985); planting did not improve regeneration (Fiedler 1982).

Simpson (1990) provided guidelines for regenerating ABLA/XETE stands in Idaho. Shelter for seedlings is important on dry, cold sites. Complete overstory removal is not recommended for sites where *Lupinus argenteus*, *Pteridium aquilinum*, or *Rudbeckia occidentalis* could expand after disturbance; *Lupinus argenteus* is very attractive to pocket gophers (Cooper and others 1991; Simpson 1990). Woody debris is necessary to shelter seedlings, especially Engelmann spruce, on dry sites. Woody debris is also the source of soil wood, which nurtures ectomicorrhizal fungi, acidifies the soil (Harvey 1982), and protects the soil from high-intensity rain in summer and frost heave in winter (DeByle 1981; Fiedler and others 1985). Graham and others (1994) recommended leaving 9 to 18.5 tons per acre of woody debris larger than 3 inches in diameter after harvesting ABLA/VAGL stands in the Payette National Forest; they recommended leaving 12 to 23 tons per acre on ABLA/XETE stands in the Lolo National Forest, MT.

Fire Group Five: Moist, Lower Subalpine Habitat Types

Abies lasiocarpa/Calamagrostis canadensis h.t. - *Calamagrostis canadensis* phase (ABLA/CACA-CACA), subalpine fir/bluejoint - bluejoint phase+

Abies lasiocarpa/Calamagrostis canadensis h.t. - *Ledum glandulosum* phase (ABLA/CACA-LEGL), subalpine fir/bluejoint - Labrador-tea phase+

Abies lasiocarpa/Calamagrostis canadensis h.t. - *Ligusticum canbyi* phase (ABLA/CACA-LICA), subalpine fir/bluejoint - Canby's ligusticum phase

Abies lasiocarpa/Calamagrostis canadensis h.t. - *Vaccinium caespitosum* phase (ABLA/CACA-VACA), subalpine fir/bluejoint - dwarf huckleberry phase+

Abies lasiocarpa/Clintonia uniflora h.t. - *Clintonia uniflora* phase (ABLA/CLUN-CLUN), subalpine fir/queencup beadlily - queencup beadlily phase+

Abies lasiocarpa/Clintonia uniflora h.t. - *Menziesia ferruginea* phase (ABLA/CLUN-MEFE), subalpine fir/queencup beadlily - menziesia phase+

Abies lasiocarpa/Clintonia uniflora h.t. - *Xerophyllum tenax* phase (ABLA/CLUN-XETE), subalpine fir/queencup beadlily - beargrass phase+

Abies lasiocarpa/Menziesia ferruginea h.t. - *Coptis occidentalis* phase (ABLA/MEFE-COOC), subalpine fir/menziesia - western goldthread phase+

Abies lasiocarpa/Menziesia ferruginea h.t. - *Luzula hitchcockii* phase (ABLA/MEFE-LUHI), subalpine fir/menziesia - smooth woodrush phase

Abies lasiocarpa/Menziesia ferruginea h.t. - *Vaccinium scoparium* phase (ABLA/MEFE-VASC), subalpine fir/menziesia - grouse whortleberry phase+

Abies lasiocarpa/Menziesia ferruginea h.t. - *Xerophyllum tenax* phase (ABLA/MEFE-XETE), subalpine fir/menziesia - beargrass phase+

Abies lasiocarpa/Streptopus amplexifolius h.t. - *Ligusticum canbyi* phase (ABLA/STAM-LICA), subalpine fir/twisted-stalk - Canby's ligusticum phase+#

Abies lasiocarpa/Streptopus amplexifolius h.t. - *Menziesia ferruginea* phase (ABLA/STAM-MEFE), subalpine fir/twisted-stalk - menziesia phase#

Tsuga heterophylla/Menziesia ferruginea h.t. (TSHE/MEFE), western hemlock/menziesia

Tsuga mertensiana/Clintonia uniflora h.t. - *Menziesia ferruginea* phase (TSME/CLUN-MEFE), mountain hemlock/queencup beadlily - menziesia phase+

Tsuga mertensiana/Clintonia uniflora h.t. - *Xerophyllum tenax* phase (TSME/CLUN-XETE), mountain hemlock/queencup beadlily - beargrass phase+

Tsuga mertensiana/Menziesia ferruginea h.t. - *Luzula hitchcockii* phase (TSME/MEFE-LUHI), mountain hemlock/menziesia - smooth woodrush phase

Tsuga mertensiana/Menziesia ferruginea h.t. - *Xerophyllum tenax* phase (TSME/MEFE-XETE), mountain hemlock/menziesia - beargrass phase+

Tsuga mertensiana/Streptopus amplexifolius h.t. - *Luzula hitchcockii* phase (TSME/STAM-LUHI), mountain hemlock/twisted-stalk - smooth woodrush phase

Tsuga mertensiana/Streptopus amplexifolius h.t. - *Menziesia ferruginea* phase (TSME/STAM-MEFE), mountain hemlock/twisted-stalk - menziesia phase#

+May be dominated in early succession by lodgepole pine.
#May be in the Grand Fir Mosaic ecosystem; see table 29.

Vegetation

The habitat types of Fire Group Five are most common on northwest- to east-facing slopes, riparian and poorly drained subalpine sites, and moist frost pockets. Although they can be found at elevations as low as 3,300 feet, most occur between 5,000 and 6,500 feet. Where Group Five stands are narrow, flanking a spring or stream, their fire regime is strongly influenced by that of neighboring stands, mostly in Fire Group Four. Where the habitat types of Fire Group Five intergrade with those of Groups Four and Six, their fire regimes and successional patterns may be intermediate between those described in this report.

Forests in Fire Group Five have substantial herbaceous and shrub cover, and often have a closed canopy (fig. 23, table 25). Climax stands are dominated by subalpine fir and mountain hemlock (and western hemlock in the TSHE/MEFE habitat type). Large spruces persist for centuries in old-growth stands. A variety of species, including climax species and spruce, occur in early succession. Seral lodgepole pine can dominate in several habitat types, but it dies out 120 to 160 years after stand establishment (Cooper and others 1991). Western larch is common on sites with good drainage. Douglas-fir, grand fir, and western white pine occur on moderate sites, but rarely dominate. Whitebark pine intergrades with lodgepole pine at high elevations (discussed in Fire Group Six).

Menziesia ferruginea and *Vaccinium globulare* (intergrading with *Vaccinium membranaceum*) dominate the shrub layer in many Group Five stands. *Rhododendron albiflorum* is important in the Kaniksu National Forest. Other common shrubs include *Alnus sinuata*, *Amelanchier alnifolia*, *Ledum glandulosum*, *Linnaea borealis*, *Lonicera utahensis*, *Pachistima myrsinites*, *Ribes lacustre*, *Rosa gymnocarpa*, *Rubus parviflorus*, *Sorbus scopulina*, and *Vaccinium scoparium*.

The herbaceous layer on Group Five sites contains ferns and forbs characteristic of wet or poorly drained sites (*Aconitum columbianum*, *Athyrium filix-femina*, *Dodecatheon jeffreyi*, *Mitella breweri*, *Senecio triangularis*, *Trautvetteria caroliniensis*, and *Veratrum viride*) as well as species characteristic of moderate sites (*Anemone piperi*, *Arnica latifolia*, *Chimaphila umbellata*, *Clintonia uniflora*, *Coptis occidentalis*, *Galium triflorum*, *Goodyera oblongifolia*, *Ligusticum canbyi*, *Osmorhiza chilensis*, *Pyrola asarifolia*, *Pyrola secunda*, *Smilacina stellata*, *Streptopus amplexifolius*, *Thalictrum occidentale*, *Trillium ovatum*, *Viola orbiculata*, and *Xerophyllum tenax*). *Calamagrostis canadensis* is common on wet sites; *Bromus vulgaris* and *Carex geyeri* occur in mesic stands.

Fuels

Fuels in Group Five (table 25) are similar to those in Fire Group Four. Duff may be considerably heavier on Group Five sites, and downed woody fuel loadings may be slightly heavier because of the large size attained by overstory spruce and the longer fire-free intervals that characterize Group Five. Brown and Bradshaw (1994) described fuel models for Engelmann spruce stands in Fire Group Five in the Selway-Bitterroot Wilderness. They used the following loadings (tons per acre) for surface fuels: litter, 0.6; duff, 40.5; herbs, 0.2; and shrubs, 0.1. Dead and downed woody fuels on three moist, lower subalpine sites in the Selway-Bitterroot Wilderness averaged 38.4 tons per acre (Walker 1973). In western Montana habitat types similar to those of Fire Group Five, total downed woody fuels ranged from 6.5 to 72.6 tons per acre (Fischer 1981c). The latter occurred in a 140 year old ABLA/CLUN-MEFE stand codominated by Engelmann spruce, subalpine fir, and Douglas-fir. Fuel loadings after timber harvest can be much higher. In western Montana, average fuel loadings in clearcut ABLA/CLUN stands were as follows: 26 tons per acre duff (5.1 inches deep), 1.5 tons per acre needles, and 112 tons per acre dead and downed woody fuels (Beaufait and others 1977).

During most summers, moist Group Five stands support a lush understory that impedes fire spread. These stands are more susceptible to damage from fires that sweep in from adjoining areas than from fires starting within the stands. Stands 5A and 5B (fig. 23, table 25) are partially open and have only partial shrub cover; low-severity fire would be more likely to carry in these stands than in forests with dense, tall shrubs and herbs (Stands 5C, 5D, 5E). The combination of deep duff with heavy dead and downed fuels in Stand 5B could support severe surface fire after a long period of drying. In contrast, the light fuels, high crowns, and sparse tree regeneration in Stand 5D contribute to low potential for severe fire.

In subalpine forests of the Rocky Mountains and Pacific Northwest, fire intensity is limited in most years by fuel conditions (Agee 1993). Williams and Rothermel (1992) described Group Five habitat types as having "the either/or dynamics of inconsequential or severe fire behavior." Duff is often deep, fuel loads may be heavy, and live fuels are often vertically continuous. However, fuels dry very slowly. Under most conditions, ignitions either burn very small

Figure 23—Vegetation and fuels in Fire Group Five. A. Stand 5A, ABLA/CLUN-XETE habitat type on south-facing bench west of Priest Lake, Kaniksu National Forest. Overstory contains a mixture of medium-sized lodgepole pine, western larch, western white pine, Engelmann spruce, and subalpine fir. B. Stand 5B, southwest-facing slope, Powell District, Clearwater National Forest. Engelmann spruce and subalpine fir dominate; a few lodgepole pine are present, standing 25 feet taller than dominants. C. Stand 5C, an open forest in TSHE/MEFE habitat type north of Gisborne Mountain, Priest River Experimental Forest. Large western larch dominate overstory; subalpine fir and western hemlock dominate sapling size class. D. Stand 5D, steep east-facing slope, Avery District, St. Joe National Forest. E. Stand 5E, small riparian site in ABLA/STAM-MEFE habitat type north of Gisborne Mountain, Priest River Experimental Forest. Subalpine fir and Engelmann spruce dominate; understory herbs and shrubs are dense and tall. Photos 5B and 5D by Jim Mital.

Table 25—Stand characteristics and fuel loadings in some Group Five stands. Fuel loadings are in tons/acre. Stands 5B and 5D are shown in figure 23. Stand 5F is on a northwest-facing slope, Pierce District, Coeur d'Alene National Forest. Stand 5G is on an east-facing slope in the St. Maries District, St. Joe National Forest. Stand 5H is on a southwest-facing slope, Bonners Ferry District, Kaniksu National Forest; a few medium-sized whitebark pine are present. Stand 5I is on a steep, northwest-facing slope near Orogrande Summit, Red River District, Nez Perce National Forest. A few medium-sized whitebark pine and lodgepole pine are present. (Data were provided by Jim Mital and are on file at Intermountain Fire Sciences Laboratory, Missoula, MT.)

Stand No.	Habitat type-phase	Age	Tree spp.	Canopy cover	Litter, duff depth	Dead and down load by size class (inches) 0-¼	¼-1	1-3	3+ sound	3+ rotten	Total dead and down load
		Years		Percent	Inches	Tons per acre					
5B[a]	ABLA/CLUN-MEFE	140	PIEN ABLA	30 10	4.0	0.1	0.5	3.4	10.2	2.6	16.8
5D	TSME/MEFE-XETE	120	TSME	60	0.5	0.0	0.8	0.4	1.9	0.0	3.1
5F	ABLA/CLUN-MEFE	80	ABGR PSME ABLA PIEN	70 20 10 10	3.0	0.1	1.8	0.5	2.7	8.2	13.3
5G	TSME/MEFE-XETE	143	TSME ABLA	40 10	3.1	0.0	0.5	1.1	0.8	0.0	2.4
5H	ABLA/MEFE-LUHI	200	ABLA	30	2.7	0.0	0.2	0.4	1.7	13.3	15.6
5I	ABLA/MEFE-LUHI	120	ABLA PIEN	30 10	0.3	0.1	0.5	0.8	7.8	5.4	14.6

[a]Refers to stand number in text.

areas or burn large areas in a patchy pattern. With sustained drying, however, the potential for severe fire increases. Fires become persistent and very difficult to suppress. Where understory trees are dense or overstory trees are draped with arboreal lichens, such fires can easily spread into crowns. Even if a severe surface fire does not crown, overstory trees are likely to be killed by cambium heating. These characteristics of Group Five stands limit the number of days when prescribed natural fires will burn significant areas and when management-ignited fires can be conducted effectively and safely.

Role of Fire

Presettlement fires occurred less frequently and burned less uniformly in Fire Group Five than in Fire Group Four (table 26). In the Selway-Bitterroot Wilderness, Group Five habitats occur mainly on moist, north-facing slopes. In presettlement times, the mean interval between stand-replacing fire in these stands was 174 years (Barrett and Arno 1991); a few fires left stands of mixed ages with scattered fire-scarred trees, indicating mixed-severity fire. The mean interval between stand-replacing fires for Group Four habitat types in the same area was 117 years (table 23). In the Selway District, Nez Perce National Forest, Group Five stands were characterized by a mixed-severity fire regime, whereas Group Four stands typically burned in stand-replacing fire (Green 1994). Broken topography further reduces the likelihood of fire in Group Five stands. In subalpine forests of the Priest River drainage, Kaniksu National Forest, stands on sheltered, east-facing slopes showed very little evidence of fire in the previous 250 years (Arno and Davis 1980). Very moist Group Five stands are difficult to burn except during extremely dry conditions, but they are also small or narrow and thus vulnerable to fires that move in from adjacent slopes.

In many forests of the Northern Rocky Mountains outside northern Idaho, intervals between fires in presettlement times were longer in moist than dry subalpine stands (Barrett and others 1991; Hawkes 1980; Romme and Knight 1981). Nonlethal fire was also less frequent on moist than dry sites. Seven to 50 percent of mature ABLA/MEFE stands in western Montana showed evidence of nonlethal underburning; 40 to 67 percent of ABLA/XETE stands showed evidence of underburns (Arno and others 1985).

Although lightning strikes are frequent in Fire Group Five (Arno and Davis 1980; Fowler and Asleson 1984), few large fires apparently originated in these stands (Barrett 1982). Most large fires probably moved in from drier sites during severe fire weather. According to Heinselman (1981), the fire regime in subalpine forests consists of infrequent crown fire and occasional

Table 26—Presettlement fire regimes for Fire Group Five habitat types in northern Idaho. Locations of stands are shown in figure 1. Mean fire intervals are computed from stand mean fire intervals for the study area.

Location, habitat types, cover	Fire severity	Years: Mean fire interval	Years: Number of stands
Priest River Basin[a]:			
—ABLA series, broken terrain	Low to moderate	>150	
Selway-Bitterroot Wilderness[b]:			
—ABLA/CLUN,/MEFE	Stand replacing	174	13
Selway District, Nez Perce National Forest[c]: ABLA/MEFE,/CLUN			
—Subalpine fir, spruce, lodgepole cover	Mixed	27	3

[a]Arno and Davis (1980).
[b]Barrett and Arno (1991), Brown and others (1994, 1995).
[c]Green (1994).

severe surface fire. Mutch (1992) reported that fires in this fire regime often burn 5,000 to 100,000 acres.

Tree regeneration on reburns in moist subalpine habitat types is variable. In the Clearwater National Forest, many reburned north-facing slopes were well stocked after 62 years without fire (Barrett 1982), but one site had only 25 percent tree canopy cover.

Most historic fire return intervals in Fire Group Five were longer than the period of effective fire exclusion has been, so fire exclusion has not measurably altered the structure and composition of Group Five stands (Arno and Davis 1980; Barrett and others 1991; Green 1994). Nevertheless, variety in stand structure and fuels, created historically by mixed-severity fire and occasional severe fire, has probably decreased. The ecological implications of such subtle changes in forests with long-interval fire regimes are unknown (Arno and Brown 1991). Effects may include increased dominance by climax species, expansion of root disease centers, and increased vertical continuity of fuels.

Forest Succession

Forest succession has not been described for Fire Group Five habitat types in northern Idaho. Our descriptions of succession are based on the species composition of mature stands in Idaho (Cooper and others 1991) and western Montana (Habeck 1967), succession in the ABLA/MEFE habitat type in western Montana (Arno and others 1985), and references to autecological characteristics of dominant tree species.

Understory species that increase after wildfire or broadcast burning on ABLA/MEFE sites in western Montana include *Alnus sinuata*, *Epilobium angustifolium*, *Salix scouleriana*, and *Senecio triangularis* (Arno and others 1985). *Vaccinium globulare* increased after moderate-severity broadcast burns, but decreased after severe fire. *Lonicera utahensis*, *Pachistima myrsinites*, and *Rubus parviflora* changed little in response to fire; *Menziesia ferruginea* decreased after burning and required 30 to 50 years to reach the levels observed in undisturbed stands.

Most Group Five stands regenerate readily after fire. Species composition varies because of variation in drainage, moisture and temperature regimes, seed source, and fire history. Patchy, mixed-severity burns further complicate structural development and species composition in Group Five. Where severe fires were less than about 160 years apart in presettlement times, lodgepole pine may dominate seral stands. Since this pattern is common in Fire Group Four, the reader is referred to Pathway 4.2 for its description. Lodgepole pine may also codominate with Engelmann spruce (Pathway 5.1), or may occur in combination with other seral species and climax species (Pathway 5.2). Cold temperatures, wet soils, and luxuriant undergrowth favor early dominance by Engelmann spruce and climax species, especially if long fire-free intervals have excluded lodgepole pine (Pathway 5.3). Stands that had adequate drainage before fire follow this pathway if water tables rise appreciably after canopy removal.

The successional pathways are qualitative guides. Actual succession on a given site may follow a path intermediate between or diverging from those described here.

Pathway 5.1. Succession Dominated by Lodgepole Pine and Engelmann Spruce—Lodgepole pine and Engelmann spruce are the only major seral species listed by Cooper and others (1991) for the cool, mesic to wet habitat types of the ABLA series (ABLA/CACA, ABLA/STAM, and ABLA/MEFE). Succession on these sites probably resembles that described for the "cold phase" of the ABLA/MEFE habitat type in western Montana (Arno and others 1985).

Following stand-replacing fire, an herbaceous stage is followed by vigorous shrub development (fig. 24 A). (Subsequent references in this section are to fig. 24.) Species composition depends on fire severity, seed source, and soil moisture regime. On very moist ABLA/MEFE stands in western Montana, surface water appeared after canopy removal and wet-meadow species dominated until tree regeneration reached the pole stage, when *Menziesia* and *Vaccinium* regained understory dominance (Arno and others 1985).

Seedlings of lodgepole pine and Engelmann spruce colonize exposed mineral soil, usually regenerating burned ABLA/MEFE stands in western Montana within 10 years (Arno and others 1985) (B). The proportion of lodgepole pine is higher after high- than low-severity fire. Regeneration of seral species may be accompanied by subalpine fir (and mountain hemlock and western hemlock on sites in their respective habitat type series); however, these species do not dominate until lodgepole pine declines. In the pole stage (C1), rapidly growing lodgepole pines overtop other species. Low-severity fire favors lodgepole pine (C2); severe fire returns the stand to herbs and shrubs (A).

Mature stands contain lodgepole pine and Engelmann spruce in the overstory (D1); the multi-age understory contains spruce and subalpine fir. Low-severity fires thin the stand, remove regeneration, and create scattered openings in which Engelmann spruce and lodgepole pine reproduce.

Lodgepole pine dies out in subalpine stands of northern Idaho within 120 to 160 years of stand origin (Cooper and others 1991), more quickly on moist than dry sites (Pfister and Daubenmire 1975). After lodgepole pine declines, mature stands are dominated by spruce and fir (E). Low-severity fire and other disturbances create openings and thin regeneration, providing microsites for spruce establishment. Engelmann spruce can live for 300 years or more and codominate with subalpine fir in climax stands (Cooper and others 1991).

Pathway 5.2. Succession Dominated by a Mixture of Seral Species—On mesic subalpine sites, particularly those in the ABLA/CLUN and TSME/CLUN habitat types, a mixture of tree species dominates succession. Patchy or mixed-severity fires contribute to a complex mosaic of vegetation, with different species dominating on adjacent, similar sites. Stand-replacing fire often leaves mature western larch and may leave Douglas-fir relict trees; if subsequent seed production is high, these species dominate subsequent stand composition.

After stand-replacing fire, herbs and shrubs sprout vigorously (fig. 25 A). (Subsequent references in this section are to fig. 25.) A mixture of seral tree species

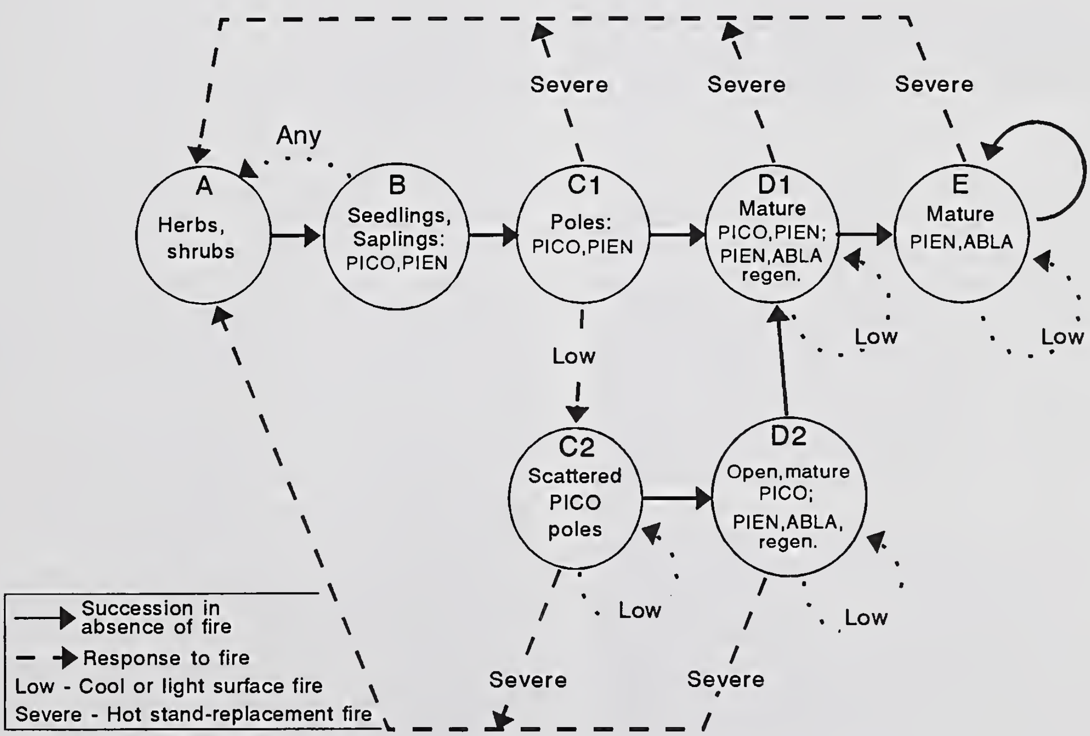

Figure 24—Pathway 5.1. Hypothetical fire-related succession for Fire Group Five stands where lodgepole pine codominates seral stands with Engelmann spruce. Succession is shown here for stands in the subalpine fir series.

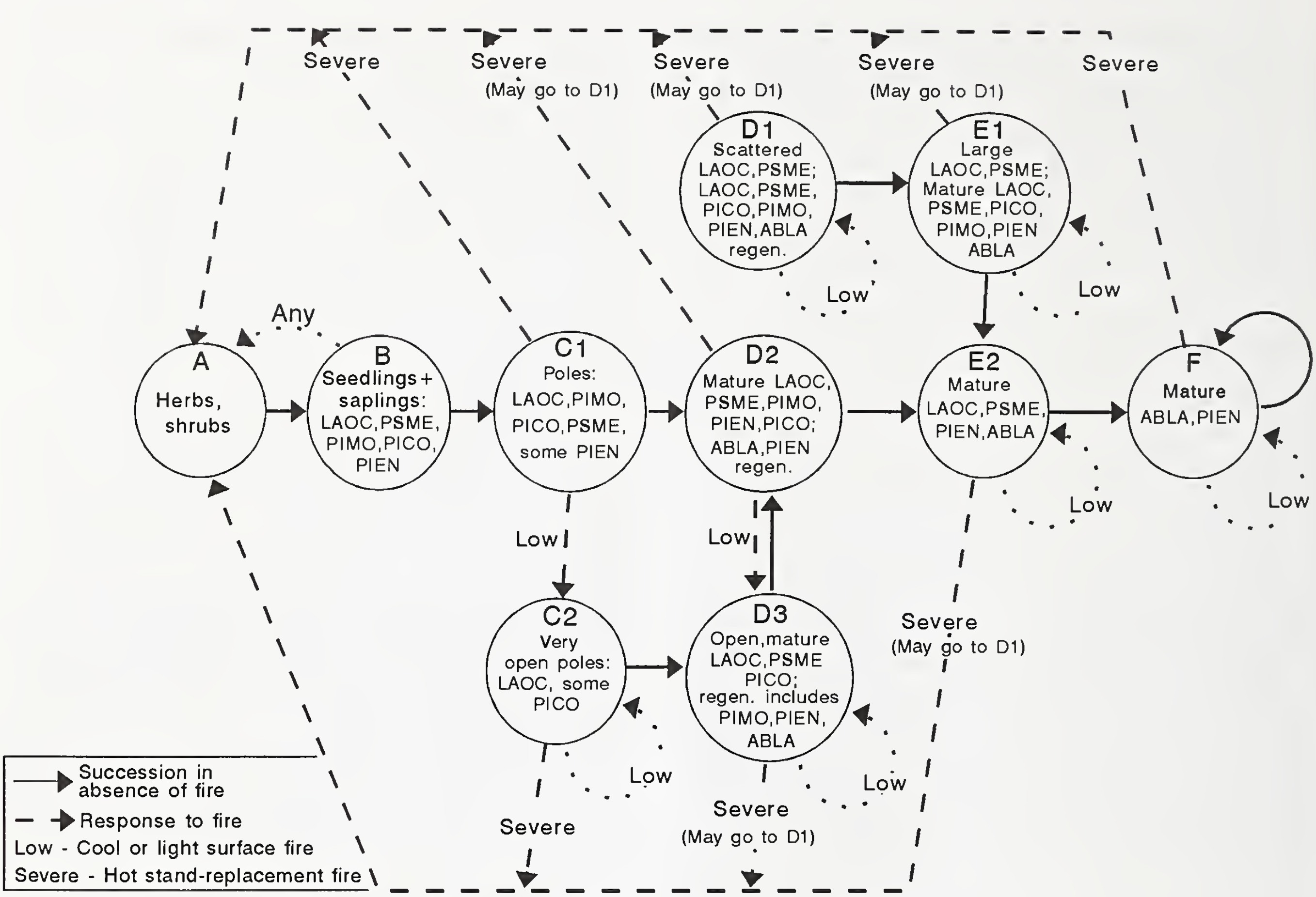

Figure 25—Pathway 5.2. Hypothetical fire-related succession for Fire Group Five stands where early succession is dominated by a combination of seral species. Succession is shown here for stands in the subalpine fir series. In the TSME and TSHE series, mountain hemlock and western hemlock occur in mixtures with subalpine fir and may eventually dominate.

establishes on recent burns (B). Western larch, Douglas-fir, and western white pine regenerate readily at low elevations; at higher elevations and on cold sites, Douglas-fir and western white pine give way to lodgepole pine and Engelmann spruce. Climax species and grand fir may regenerate successfully, but they do not dominate until the stand matures. This mixture of species is similar to that described for warm ABLA/MEFE stands in western Montana (Arno and others 1985).

The fastest growing species (western larch and the pines) dominate the pole stage (C1). Western white pine varieties that are not rust resistant are thinned or eliminated by white pine blister rust. Low-severity fire eliminates Engelmann spruce; survival of other seral species is variable, although western larch may be favored (C2). Subsequent regeneration by western larch and the pines requires substantial duff reduction.

In stands that mature without fire, seral species dominate the overstory, and climax species and spruce dominate the understory (D2). Low-severity fire removes regeneration, opens the stand, and increases the relative dominance of western larch, Douglas-fir, and lodgepole pine (D3). Severe fire kills nearly all trees and may return the site to herbs and shrubs (A). However, mature western larch and occasional Douglas-fir, especially open-grown trees, can withstand even severe fire (D1). Clusters of such relict trees often occur on sites sheltered from extreme fire behavior by topographic features. Seedlings from relict trees usually dominate regeneration (E1).

Lodgepole pine and western white pine are eventually eliminated by mountain pine beetle and other agents of mortality (E2); western larch and Douglas-fir persist for centuries. Climax species and Engelmann spruce eventually dominate (F). Fires of very low severity alter stand structure, thinning the understory and producing injuries that increase mortality from stem and root disease. Severe fires lead to complete stand replacement (A).

Pathway 5.3. Succession Dominated by Engelmann Spruce and Climax Species—Many sites in the TSME/MEFE, TSME/STAM, AND TSHE/MEFE habitat types regenerate after disturbance with Engelmann spruce and climax species; occasionally even spruce is absent (Cooper and others 1991). The regenerating species persist throughout stand development and codominate climax stands. This successional pathway is particularly prevalent at high elevations, but it has not been described in detail. Preburn species composition, fire severity, and alterations in the water table control the species dominating the herb/shrub stage. Trees either regenerate soon after fire or more slowly, under the shelter of the shrub layer. Low-severity fire alters stand structure, but has little effect on species composition.

Fire Management Considerations

Management objectives in Group Five stands include wilderness perpetuation, watershed protection, wildlife habitat maintenance, and timber production. Fire exclusion has not yet measurably altered the structure and composition of Group Five stands (Arno and Davis 1980; Barrett and others 1991; Green 1994). The Selway-Bitterroot Wilderness has been managed since 1979 under a policy that allows prescribed natural fire. The area burned annually since 1979 in the Engelmann spruce fire regime type (mostly Group Five habitat types) is not significantly different from the area burned annually in presettlement times, although the recent period has had more nonlethal fire and less stand replacement fire than the presettlement period (Brown and others 1994). Where subalpine landscapes contain increasingly continuous stands of mature Engelmann spruce and subalpine fir, they may be increasing in flammability and vulnerability to insects and disease (Covington and others 1994).

Moist subalpine stands can act as firebreaks during moderate weather, but not during severe fire weather (Agee 1993). Where duff is deep, Group Five stands can harbor smoldering fires for long periods, increasing the potential for numerous fires to break out when burning conditions become severe. Fire suppression efforts that disturb forest soils on moist sites can produce long-lasting damage (Bradley and others 1992a). Very moist stands are mostly small and narrow, but they have more fragile soils and are less resilient to disturbance than adjacent, drier stands. Canopy removal in Group Five may raise the water table (Arno and others 1985).

Group Five stands with mature, lichen-draped trees provide winter forage for woodland caribou in the Idaho Panhandle National Forests. Stand-replacing fire in caribou habitat eliminates arboreal lichens for 50 years or more (Edwards and others 1960), and may reduce cover of *Vaccinium* species.

Management ignitions are used in Group Five to reduce fuel loadings and prepare harvested sites for regeneration, and can be used to increase structural heterogeneity across the landscape. Because Group Five stands are naturally moist, however, opportunities for effective prescribed burning are few, and occur mainly during late summer (Williams and Rothermel 1992). Guidelines for using fire to regenerate Engelmann spruce (Roe and others 1970) indicate that effective burns must expose mineral soil but leave substantial woody residue to shade seedlings and provide nutrients; these requirements are very sensitive to duff moisture content. Burns that are conducted when duff moisture is high, especially on north-facing slopes, may fail to reduce duff sufficiently for tree regeneration and instead produce shrubfields. Incomplete burning produced dense shrub cover in a clearcut ABLA/CLUN stand in western Montana; the site was reburned successfully and regenerated 14 years later (Shearer and Schmidt 1982). Burning slash in large windrows or piles can alter the physical structure of the soil, producing conditions adverse to revegetation. Fifteen years after treatment of subalpine stands in western Montana, regeneration density was 85 percent less in severely burned slash piles than on unburned sites (Vogl and Ryder 1969).

Natural regeneration after fire is often plentiful in Group Five, although shade is needed on some sites. In ABLA/CLUN and ABLA/MEFE stands in western Montana, regeneration was most rapid and dense after wildfire, and broadcast burned clearcuts regenerated more successfully than scarified or untreated clearcuts (Fiedler 1982; Shearer 1984). The decomposition of charred duff prolonged receptive seedbed conditions (Shearer and Stickney 1991). On ABLA/CLUN sites in western Montana, tree regeneration benefited from partial shade on south-facing slopes, but not on north-facing slopes (Shearer 1976). On burned clearcuts, deer mouse and chipmunk (*Eutamias* spp.) populations may be larger than in uncut stands and may damage tree reproduction (Halvorson 1981).

Fire can be used to control species composition of regeneration in Group Five stands. Clearcuts in ABLA/MEFE and TSME/MEFE stands in the St. Joe National Forest produced ample subalpine fir and mountain hemlock regeneration with and without site preparation. Engelmann spruce and western larch, however, regenerated more successfully after burning or heavy scarification (Boyd and Deitschman 1969). In the ABLA/MEFE habitat type in western Montana, lodgepole pine dominated after wildfire and severe broadcast burns; subalpine fir dominated after partial cutting (Arno and others 1985). Western larch regeneration was most plentiful and subalpine fir least plentiful on burned clearcuts in the ABLA/CLUN habitat type in western Montana. On unburned sites,

Douglas-fir was most plentiful and lodgepole pine and spruce were least plentiful (Shearer 1984).

Arno and others (1985) described differences in the herb/shrub stage attributable to site preparation after clearcutting in the ABLA/MEFE habitat type in western Montana. Very moist sites with no treatment had standing water after cutting; the herbaceous layer was dominated by *Calamagrostis canadescens* and other wet-site species. These species compete with tree regeneration in moist subalpine forests of northern Idaho (Cooper and others 1991). Better drained sites treated with low-severity burns had profuse *Epilobium angustifolium*, followed in succession by resprouting *Menziesia ferruginea* and *Vaccinium globulare* (Arno and others 1985). Severe fire caused a shift in understory species. *Ribes viscosissimum* germinated on sites with soil-stored seed, and *Salix scouleriana* colonized some stands from wind-blown seed.

Fire Group Six: Upper Subalpine Habitat Types

Abies lasiocarpa/Luzula hitchcockii h.t. (ABLA/LUHI), subalpine fir/smooth woodrush
Larix lyallii-Abies lasiocarpa communities (LALY-ABLA), alpine larch-subalpine fir communities
Pinus albicaulis-Abies lasiocarpa communities (PIAL-ABLA), whitebark pine-subalpine fir communities
Tsuga menziesia/Luzula hitchcockii h.t. (TSME/LUHI), mountain hemlock/smooth woodrush

Vegetation

Fire Group Six consists of high, cold subalpine habitat types that occur near timberline. Mature forests are often open, with trees growing in clusters (fig. 26). On severe sites, tree height is less than 60 feet (Cooper and others 1991). Many upper subalpine forests in northern Idaho are dominated by a mixture of whitebark pine, lodgepole pine, Engelmann spruce, mountain hemlock, and subalpine fir. (For sites where lodgepole pine is dominant, refer to Fire Groups Four and Five.) Whitebark pine dominance increases with increasing elevation and site severity. However, whitebark pine has declined severely in recent decades due to the combined effects of mountain pine beetle and white pine blister rust (Kendall and Arno 1990). Some rust resistance occurs in whitebark pine, and breeding programs for rust resistant varieties are being developed (Hoff and others 1994); but 90 percent mortality of whitebark pine over most of northern Idaho has altered species relationships, stand development, and successional pathways on Group Six sites from their historic patterns.

Figure 26—Vegetation and fuels in Fire Group Six. Stand 6A, in the Salmon District, Nez Perce National Forest, is on a northwest-facing slope at 8,096 feet elevation; the overstory is dominated by whitebark pine, the understory by subalpine fir. Photo by Jim Mital.

Alpine larch has a very limited distribution in northern Idaho. It can pioneer on rockslides and talus, and also occurs on moist, high-elevation sites where winter desiccation causes high mortality in other conifers (Arno 1990; Arno and Habeck 1972). In northern Idaho, alpine larch stands occur in the Bitterroot Mountains and in the Kaniksu National Forest.

Vaccinium scoparium is widespread in Group Six stands and provides the only shrub cover on some sites. *Menziesia ferruginea*, *Lonicera utahensis*, and *Vaccinium globulare* (intergrading with *Vaccinium membranaceum*) occur occasionally (Cooper and others 1991); *Vaccinium globulare* grows only 12 to 20 inches tall on severe sites. The heath plants *Phyllodoce empetriformis* and *Cassiope mertensiana* form a dense layer on some sites.

Herbaceous species diversity is low in Group Six stands. *Xerophyllum tenax*, *Luzula hitchcockii*, *Carex geyeri*, and *Carex rossii* are common. *Luzula hitchcockii* may be associated with *Arnica latifolia* and *Polemonium pulcherrimum*. *Juncus parryi* occurs on windward, dry sites (Cooper and others 1991). Arno and Habeck (1972) described in detail the flora associated with alpine larch.

Fuels

Fire Group Six stands are characterized by relatively sparse fine fuels and moderate to heavy loadings of widely scattered, large-diameter fuels (fig. 26, table 27). Brown and Bradshaw (1994) described fuel models for stands in Fire Group Six dominated by whitebark pine in the Selway-Bitterroot Wilderness. They used the following loadings (tons per acre) for surface fuels: litter, 0.2; duff, 0.8; herbs, 0.6; and tree regeneration, 0.3. Stands dominated by alpine larch tend to have slightly more litter, less herbaceous fuels and tree regeneration, and considerably more duff (10.4 tons per acre). Stands with high subalpine fir basal area often have relatively heavy fuel loadings, so fire intensity is likely to be greater in stands where whitebark pine is seral than where it is climax (Keane and others 1990b). Because of the open structure of Stand 6A (fig. 26), fuels may dry out and carry surface fire readily; potential for torching and crowning, however, is low. Smoldering fire in the deep duff of this stand could kill many trees and understory plants. Potential for severe fire from heavy fuels on Group Six sites is mitigated by the normally cool location, the short fire season, and the sparse and discontinuous fine fuels (Arno 1966; Lasko 1990). A summary of forest inventory data from Group Six stands in the Nez Perce National Forest showed that duff depth in Group Six stands averaged 0.3 inches; dead and downed woody fuels 0.25 to 1 inch in diameter averaged 0.6 tons per acre, and larger woody fuel loadings averaged 11.3 tons per acre (Brown and See 1981). In western Montana, average downed woody fuel loadings in habitat types like those of Fire Group Six ranged from 7.0 to 25.8 tons per acre (Fischer and Bradley 1987).

Fires on Group Six sites are of low or mixed severity, except in the few stands where canopy cover is dense and fuels are heavy; this occurs where upper and lower subalpine forests intergrade and in cirque basins (Lasko 1990). Severe fires usually originate in more productive forest types at lower elevations (Arno 1986; Arno and Hoff 1989). Extensive fire spread may be most likely in early succession, when herbaceous cover provides sufficient fine fuels, and late succession, when downed woody fuels increase and shade-tolerant species provide fuel ladders (Arno and Petersen 1983; Morgan and Bunting 1990). Historically, severe fires in Group Six were probably limited to late summer and early fall (Morgan and Bunting 1990).

Role of Fire

Arno (1980) reported great variation in presettlement fire regimes on high-elevation sites in the Northern Rocky Mountains; average fire-free intervals ranged from 60 to 300 years. Mixed-severity fire was typical in stands with seral whitebark pine (Keane 1992). Whitebark pine stands in the Idaho portion of the Selway-Bitterroot Wilderness experienced stand-replacing fire every 180 years, on the average (table 28); nonlethal underburns occurred in nearly half of the stands, at average intervals of 56 years (Brown and others 1994). Many fires spread unevenly through the patchy fuels (Barrett and Arno 1991). Presettlement fire regimes in whitebark pine communities of western Montana were similar. In whitebark pine stands on the Bitterroot National Forest, 92 percent of mature stands showed evidence of nonlethal underburns (Arno 1976). Fire return intervals in whitebark pine

Table 27—Stand characteristics and fuel loadings in two Group Six stands. Fuel loadings are in tons/acre. Stand 6A is shown in figure 26. Stand 6B is on an east-facing slope at 7,519 feet elevation in the Salmon District, Nez Perce National Forest. Whitebark pine and lodgepole pine codominate, the lodgepole pine averaging 25 feet taller than whitebark pine. (Data were provided by Jim Mital and are on file at Intermountain Fire Sciences Laboratory, Missoula, MT.)

Stand No.	Habitat type-phase	Age	Tree spp.	Canopy cover	Litter, duff depth	Dead and down load by size class (inches) 0-¼	¼-1	1-3	3+ sound	3+ rotten	Total dead and down load
		Years		*Percent*	*Inches*	*Tons per acre*					
6A[a]	ABLA/LUHI	160	PIAL	60	5.6	0.0	0.0	0.7	0.0	0.0	0.7
			ABLA	30							
6B	PIAL-ABLA	164	PIAL	20	1.3	0.0	0.7	0.4	0.8	8.4	10.3
			PICO	20							
			ABLA	20							

[a]Refers to stand number in text.

Table 28—Presettlement fire regimes for Fire Group Six habitat types in the Selway-Bitterroot Wilderness (Brown and others 1995). Location of study is shown in figure 1. Mean fire intervals are computed from stand mean fire intervals.

Location, habitat types, cover	Fire severity	Years	
		Mean fire interval	Number of stands
Selway-Bitterroot: high subalpine			
—Whitebark pine-subalpine fir cover	Stand replacing	180	5
	Nonlethal	56	6
—Alpine larch in cover	Stand replacing	166[a]	9

[a]Data from Engelmann spruce fire regime type (mostly Fire Group Five) were used to represent the alpine larch type.

stands of the Bob Marshall Wilderness, MT, ranged from 55 to 304 years, with an average of 144 years (Morgan and others 1994b). Variation in fire return intervals is an important component of the fire regimes of high subalpine communities. A simulation of succession in whitebark pine stands (Keane and others 1990b) indicated that whitebark pine is less likely to maintain dominance when burned at regular 80-year intervals than when burned at irregular intervals averaging 80 years.

Tree regeneration on upper subalpine sites after severe fire is episodic. On two severe burns in western Montana, most whitebark pine regeneration established 17 to 25 years after fire, during a period with slightly higher precipitation than others years (Tomback and others 1993). Temperature extremes and dry soils on xeric sites are moderated only by snags and downed logs, so development of mature forest may be extremely slow (Arno and Hoff 1989; Gabriel 1976). Many stands above 6,000 feet in the Selway-Bitterroot Wilderness were dominated by whitebark pine before a severe fire; 60 years after the fire, shrubs still formed the dominant cover (Habeck 1972).

Low-severity fire in Group Six stands removes subalpine fir and Engelmann spruce and favors dominance by whitebark pine (if rust resistant) and lodgepole pine, if present. Whitebark pine grows faster on open sites than Engelmann spruce or subalpine fir (Tomback 1989), though it may be overtopped by lodgepole pine on moderate sites (Keane and others 1990b). Because most fires in Group Six are small and discontinuous, they help shape the complex vegetational mosaic typical of high-elevation stands.

Most whitebark pine regeneration originates from unrecovered seed caches of the Clark's nutcracker (Arno and Hoff 1989). Nutcrackers have been observed traveling more than 10 miles before caching seed, an effective means of regenerating large burns (Tomback 1994). Low-severity fire creates small openings where nutcrackers can cache seed and whitebark pine can establish successfully (Arno 1986); it may also enhance whitebark pine cone production by decreasing competition from other species (Morgan and Bunting 1990).

The ecology of whitebark pine is interwoven with that of lodgepole pine, mountain pine beetle, and introduced white pine blister rust (Hoff and Hagle 1990; Kendall and Arno 1990). As described in "Insects and Diseases," mountain pine beetle irruptions in lodgepole pine stands are related to stand structure and age, and thus to postfire succession. When beetle-caused mortality is high in lodgepole pine stands, it is followed by high mortality in neighboring whitebark pine (Gibson 1994; Kendall and Arno 1990). Dead and downed woody fuels increase following mountain pine beetle mortality (Keane and others 1990b). Heavier fuels have the potential to increase fire severity and fire-caused mortality in whitebark pine, reducing seed quantities necessary for regenerating the stand. Eighty years after a large fire in a whitebark pine stand on the Idaho-Montana border, whitebark pine regeneration was negligible (Kendall and Arno 1990). The pines probably failed to establish because seed source and seedlings were reduced by white pine blister rust. Poor whitebark pine regeneration on the 55,800 acre Sundance Burn in the Kaniksu National Forest has been attributed to lack of seed, both because many mature trees were killed by pine beetle before the fire, and because about a third of surviving, mature trees were infected with blister rust. Whitebark pine regeneration on 29 percent of sample sites had blister rust symptoms (Tomback and others 1994).

The historic role of fire in moist, high-elevation forests differed from that in communities on dry sites dominated by whitebark pine, but descriptions of these stands are few. In the Idaho portion of the Selway-Bitterroot Wilderness, data from moist lower subalpine forests were used to describe the presettlement fire regime in high-elevation stands containing alpine larch (Brown and others 1994).

Intervals between stand-replacing fires were similar to those on drier sites, but most fires were stand replacing (table 28). In alpine larch-Engelmann spruce-subalpine fir stands of Kananaskis National Park, AB, mean fire return intervals averaged 304 years and were about 80 years longer on north- than on south-facing slopes (Hawkes 1980). Alpine larch is very intolerant of shade but can grow well on sites where no other conifers thrive (Arno and Habeck 1972). It depends on a suite of ideal conditions, including mineral soil and ample moisture, for successful establishment; germinants tend to establish in even-age groves and grow very slowly for 20 to 25 years while developing a deep root system. On very good sites, alpine larch requires 75 years to reach 5 inches d.b.h. (Arno 1990).

Forest Succession

Stand-replacing disturbances are infrequent on Group Six sites and may be caused by snow and wind damage, rock slides, and talus slippage as well as fire. After severe disturbance, succession is much slower in Group Six than in lower subalpine forests. Forest succession has been described for seral and climax stands of whitebark pine in northern Idaho and western Montana (Keane and others 1990b; Morgan and others 1994b). Our descriptions of succession are based on these reports and on references to autecology of dominant species. Actual succession on a given site may follow a path intermediate between or diverging from those described here. Furthermore, blister rust has depleted whitebark pine seed production and reduced establishment so severely that historic patterns of succession may have limited usefulness for predicting current stand development.

On relatively dry sites in Fire Group Six, whitebark pine is the climax species and dominates throughout succession (Pathway 6.1). On moderate sites, a mixture of seral species dominates early succession and gives way gradually to climax species (Pathway 6.2). Where alpine larch is seral in northern Idaho, it requires disturbance to persist. Arno and Habeck (1972) described primary succession for alpine larch in Montana and British Columbia; since postfire succession has not been described, however, a pathway depicting it is not included here.

Pathway 6.1. Succession Dominated by Whitebark Pine—On dry sites in Fire Group Six, whitebark pine is a climax or long-lived seral species (Cooper and others 1991). It can become established even on large burns because of seed dispersal by nutcrackers, and usually establishes before subalpine fir and Engelmann spruce (Cooper and others 1991). If blister rust does not cause heavy mortality, whitebark pine can maintain dominance even in the absence of fire. Low-severity fire maintains an open stand structure and reduces less fire-resistant species (Keane and others 1990b). Three years after a midsummer prescribed natural fire on a moist, west-facing stand in the ABLA/LUHI habitat type in the Bob Marshall Wilderness, western Montana, Ash and Lasko (1990) found 264 whitebark pine seedlings per acre; no other tree species were represented. *Luzula hitchcockii*, *Vaccinium scoparium*, and *Xerophyllum tenax* were the dominant shrub and forb species. Total plant cover increased each year after the fire, as did total production of herbs and shrubs (fig. 27).

Pathway 6.2. Early Succession Dominated by a Mixture of Seral Species—Moderate sites in Fire Group Six can support several tree species; burning pattern and fire history determine, to some extent, the species that actually occur.

After stand-replacing fire, herbs and low shrubs dominate (fig. 28 A). (Subsequent references in this section

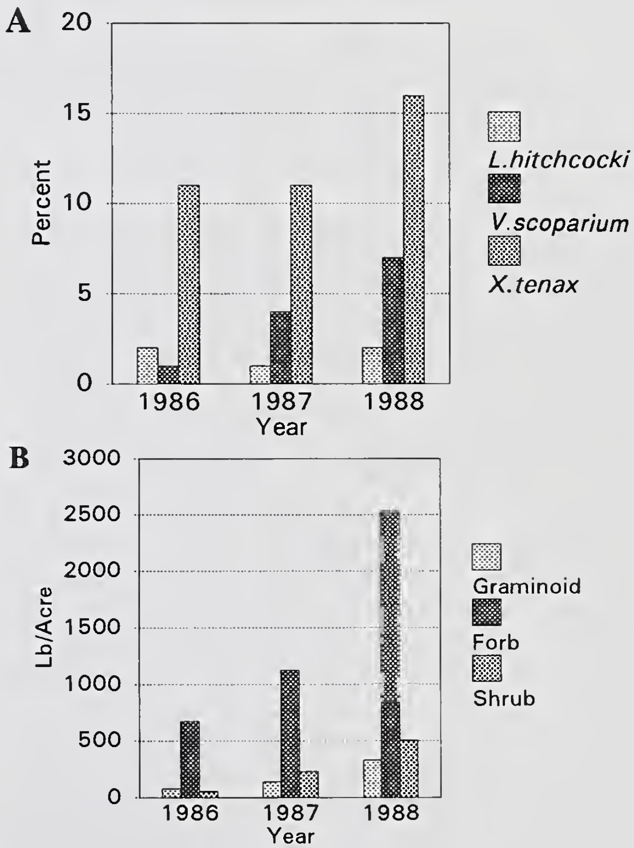

Figure 27—Recovery of herbs and shrubs after a prescribed natural fire in a 195 year old whitebark pine community in the Bob Marshall Wilderness, western Montana (Ash and Lasko 1990). A. Percent canopy cover of dominant species in the first three years after fire. B. Total biomass production in the first three years after fire.

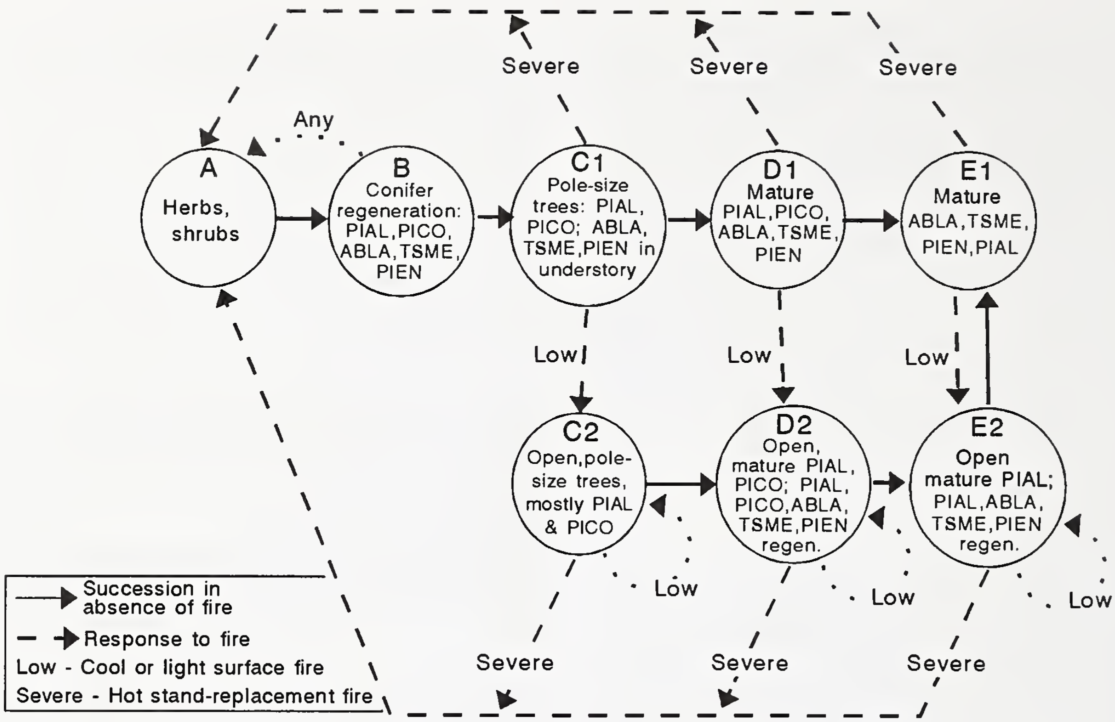

Figure 28—Pathway 6.2. Hypothetical fire-related succession for mesic stands in Fire Group Six. Succession, shown here for stands in the TSME series, is dominated by a mixture of species.

are to fig. 28.) Tree regeneration is often slow because both abundant seed and moisture are needed; these conditions do not often coincide on high subalpine sites. Prior to high blister rust mortality, whitebark pine regenerated more successfully than fir or spruce (Arno and Hoff 1990). Today, most whitebark pine regeneration is removed by blister rust. Lodgepole pine grows faster than competitors and tends to dominate early seral stands (B, C1); establishment is often in clusters due to seed caches and variable site conditions. Subalpine fir, Engelmann spruce, and mountain hemlock may become established during the same time period. Growth of a substantial population to pole size (C1) requires many decades. The site index for 50 year old subalpine fir on PIAL-ABLA sites in western Montana was 16 feet (Pfister and others 1977).

Since pines are more resistant to surface fire than their associates at high elevations, low-severity fires thin the pines and kill other trees (C2). Rust-resistant whitebark pines, and those in areas not yet severely infested by blister rust, produce plentiful seed after they are 70 to 100 years old (Kendall and Arno 1990; Morgan and Bunting 1990). Modelling of succession in a whitebark pine community near Sabe Mountain, just east of the Selway-Bitterroot Wilderness in the Idaho portion of the Bitterroot National Forest, indicated that whitebark pine will dominate or codominate with lodgepole pine if low-severity fires occur at variable intervals with an 80 year average. Lodgepole pine will be favored by fires occurring at regular 80 year intervals (Keane and others 1990b). Shade-tolerant species regenerate under the maturing canopy, and pines may become established in openings (D2). Patchy, open stands of whitebark pine mixed with shade-tolerant trees were typical of mature Group Six stands prior to fire exclusion and widespread infection by white pine blister rust.

Late seral stands in Fire Group Six (D1) contain a mixture of species. Lodgepole pine declines with fire exclusion (E1). Whitebark pine can live more than 700 years (Arno and Hoff 1989), but climax species gradually attain dominance in the absence of fire. Severe mortality from either mountain pine beetle or white pine blister rust accelerates dominance by climax species (Keane and others 1990b). Low-severity fire kills climax trees and spruce directly or leaves them vulnerable to disease and insects; in areas with low blister rust mortality, low-severity fire produces open stands dominated by whitebark pine (E2).

Fire Management Considerations

Management objectives for Group Six stands include wildlife habitat perpetuation, wilderness perpetuation, recreation, and watershed protection. Timber production is rarely an important management

objective. Whitebark pine is an important food for Clark's nutcrackers, red squirrels, grizzly bears, and black bears. Nutcrackers cache the nutritious seeds, and squirrels cache the cones during the fall. Nutcrackers prefer open areas and open whitebark pine stands for seed caches (Arno 1994). Red squirrels apparently prefer mixed stands of pine, Engelmann spruce, and subalpine fir, which provide alternative foods when whitebark cone crops are small. Because of the squirrel caches, mixed-species stands are the most favorable habitat for bears (Kendall and Arno 1990). In some areas, grizzly bears depend on whitebark pine seed stored in large cone caches for their autumn food. Decline of whitebark pine is likely to be accompanied by loss or migration of wildlife species, a combination of forces that causes the loss of historic structure and function in high subalpine stands (Hoff and others 1994; Keane and others 1994a).

Fire exclusion has increased the average interval between fires in seral whitebark pine stands of the Rocky Mountains appreciably—from less than 3 centuries to 3,000 years or more (Arno 1986). Seral whitebark pine stands are being replaced by mixed-conifer and subalpine fir forests (Arno and others 1993; Keane and others 1994a). A landscape in the Bitterroot National Forest, MT, contains Group Four and some Group Six habitat types. In 1900, 14 percent of the area was dominated by whitebark pine, but in 1990 whitebark pine was not dominant in any stands (table 24). Restoration of some lightning-ignited fires under a prescribed natural fire policy, however, does not automatically restore the historic fire regime. In the Selway-Bitterroot Wilderness, managed since 1979 under a policy allowing prescribed natural fire, the average annual area burned in recent years in whitebark pine communities is only 42 percent of that burned annually in presettlement times, for both stand-replacing and nonlethal fire (Brown and others 1994). In alpine larch communities, the fire regime of recent years appears similar to that of presettlement times.

Because Group Six stands are susceptible to fires and insect irruptions that originate at lower elevations, effective fire management requires assessment and planning for watersheds and landscapes as well as individual stands. For example, use of prescribed natural fire in whitebark pine communities is constrained by landscape considerations, since the severe fires that historically burned from lower subalpine forests into whitebark pine stands are often unacceptable as prescribed natural fires (Arno 1986). In stands where whitebark pine is seral, felling some spruce and fir would increase fuels and may enable managers to use prescribed fire under more moist conditions than would be possible in unmanaged fuels (Arno 1995).

Because whitebark pine establishes sporadically and grows slowly on Group Six sites, and because blister rust has severely reduced both seed source and regeneration, management action is probably needed to perpetuate the pine and its dependent wildlife species (Arno 1986). Modelling by Keane and others (1990b) predicted that, where blister rust infection rates are high, fire will convert climax whitebark pine forests into herbaceous and shrub communities. Rust-resistant trees in the field must be protected from fire-caused mortality to perpetuate the species, but fire exclusion reduces potential sites for seed caches and regeneration (Morgan and others 1994b). Regeneration using rust-resistant varieties is essential (Hoff and Hagle 1990). Management alternatives being investigated in whitebark pine stands in the Bitterroot National Forest, western Montana, include management-ignited fire and release cuttings to favor pine over its competitors (Arno 1994; Morgan and others 1994b).

Methods used to manage Group Six stands must have low impact because watershed and esthetic values are very high. Heavy equipment can damage the soil severely, especially on moist sites (Arno and Hoff 1990).

Fire Group Seven: Moderate and Moist Grand Fir Habitat Types

Abies grandis/Asarum caudatum h.t. - *Asarum caudatum* phase (ABGR/ASCA-ASCA), grand fir/wild ginger - wild ginger phase#

Abies grandis/Asarum caudatum h.t. - *Menziesia ferruginea* phase (ABGR/ASCA-MEFE), grand fir/wild ginger - menziesia phase#

Abies grandis/Asarum caudatum h.t. - *Taxus brevifolia* phase (ABGR/ASCA-TABR), grand fir/wild ginger - Pacific yew phase#

Abies grandis/Clintonia uniflora h.t. - *Clintonia uniflora* phase (ABGR/CLUN-CLUN), grand fir/queencup beadlily - queencup beadlily phase*

Abies grandis/Clintonia uniflora h.t. - *Menziesia ferruginea* phase (ABGR/CLUN-MEFE), grand fir/queencup beadlily - menziesia phase+

Abies grandis/Clintonia uniflora h.t. - *Physocapus malvaceus* phase (ABGR/CLUN-PHMA), grand fir/queencup beadlily - ninebark phase*

Abies grandis/Clintonia uniflora h.t. - *Taxus brevifolia* phase (ABGR/CLUN-TABR), grand fir/queencup beadlily - Pacific yew phase

Abies grandis/Clintonia uniflora h.t. - *Xerophyllum tenax* phase (ABGR/CLUN-XETE), grand fir/queencup beadlily - beargrass phase+

Abies grandis/Linnaea borealis h.t. - *Linnaea borealis* phase (ABGR/LIBO-LIBO), grand fir/twinflower - twinflower phase

Abies grandis/Linnaea borealis h.t. - *Xerophyllum tenax* phase (ABGR/LIBO-XETE), grand fir/twinflower - beargrass+

Abies grandis/Senecio triangularis h.t. (ABGR/SETR), grand fir/arrowleaf groundsel#

Abies grandis/Vaccinium globulare h.t. (ABGR/VAGL), grand fir/blue huckleberry+

Abies grandis/Xerophyllum tenax h.t. - *Coptis occidentalis* phase (ABGR/XETE-COOC), grand fir/beargrass - western goldthread+

Abies grandis/Xerophyllum tenax h.t. - *Vaccinium globulare* phase (ABGR/XETE-VAGL), grand fir/beargrass - blue huckleberry+

May be in the Grand Fir Mosaic ecosystem; see description in table 29.

* Likely to be maintained as persistent shrubfields, if burned by severe fire at intervals shorter than about 30 years.

+ May be dominated in early succession by lodgepole pine.

Where ABGR/CLUN-XETE, ABGR/LIBO-XETE, ABGR/VAGL, and ABGR/XETE phases occur adjacent to dry subalpine stands, their fire ecology resembles that of Fire Group Four. Where ABGR/CLUN-PHMA and ABGR/LIBO-LIBO phases occur adjacent to warm, dry habitat types, their fire ecology resembles that of Fire Group Two.

Vegetation

The habitat types in Fire Group Seven cover large areas in northern Idaho; they are ecologically diverse and floristically rich. Group Seven habitat types occur on dry to mesic sites, from valley bottoms to elevations as high as 6,500 feet. The vegetation varies considerably (fig. 29), even among sites in the same habitat type. Fire regimes and successional patterns are also diverse.

Grand fir is the climax species on Group Seven sites, codominating on some sites with subalpine fir. Douglas-fir is the most important seral species (Cooper and others 1991; Habeck 1985) except on moist sites, where Engelmann spruce may dominate. The presence of lodgepole pine, western larch, and western white pine depends on moderate moisture conditions and favorable fire history. Quaking aspen, paper birch, and black cottonwood are seral on some sites (Drew 1967; Habeck 1972). Ponderosa pine is a minor seral tree in Group Seven but, because of its longevity, it can influence stand structure and composition for several centuries after establishment.

Numerous shrub species occur in Group Seven stands, and shrubs often dominate succession for many years. On dry to moderate sites, the shrub layer often includes a mixture of the following: *Acer glabrum*, *Amelanchier alnifolia*, *Ceanothus* species, *Holodiscus discolor*, *Linnaea borealis*, *Lonicera utahensis*, *Physocarpus malvaceus*, *Rosa gymnocarpa*, *Rubus parviflorus*, and *Symphoricarpos albus*. *Taxus brevifolia* occurs on warm, mesic slopes and benches. *Alnus sinuata* invades wet sites after disturbance. *Menziesia ferruginea* and *Vaccinium globulare* (intergrading with *Vaccinium membranaceum*) form dense cover on high-elevation sites.

Herbaceous species composition in Group Seven stands varies with moisture and temperature (Cooper and others 1991). Wet sites are characterized by *Athyrium filix-femina*, *Senecio triangularis*, and *Trautvetteria caroliniensis*. *Xerophyllum tenax* occurs in dry stands. Other forbs that occur widely in Group Seven habitat types include: *Adenocaulon bicolor*, *Arnica cordifolia*, *Arnica latifolia*, *Asarum caudatum*, *Clintonia uniflora*, *Coptis occidentalis*, *Disporum hookeri*, *Galium triflorum*, *Polystichum munitum*, *Smilacina stellata*, *Tiarella trifoliata*, *Viola glabella*, and *Viola orbiculata*. Grasses include *Bromus vulgaris* and *Calamagrostis canadensis*.

Ferguson (1991) described the Grand Fir Mosaic Ecosystem, a vegetation community containing many Group Seven sites, in which forest structure and composition are somewhat unique. Snow melts later on Mosaic sites than on non-Mosaic sites in similar habitat types; soil temperatures remain cooler, and fluctuations in soil water stress and diurnal temperature are less severe. Mild environmental conditions have shaped plant communities that are rich and productive, but also highly sensitive to disturbance. The Grand Fir Mosaic occurs on the Nez Perce, Clearwater, and southern parts of the St. Joe National Forests. Table 29 lists criteria for identifying late-seral to climax stands in the Mosaic. Grand fir and Engelmann spruce dominate, with mountain hemlock and subalpine fir at higher elevations and western redcedar at low elevations. Seral tree species are not well represented. *Taxus brevifolia* is important in the shrub layer.

Fuels

Some of the most productive forests in northern Idaho grow in Fire Group Seven stands, and these stands tend to produce heavy fuels as well. In the Selway-Bitterroot Wilderness, total fuel loading in stands of the grand fir series averaged 37 tons per acre, with duff comprising the majority of fuel, 30 tons per acre (Habeck 1973). Loadings used in Brown and Bradshaw's (1994) fuel models for Group Seven stands dominated by Douglas-fir in the Selway-Bitterroot Wilderness were similar. On two ABGR/CLUN stands (one in early succession and one 215 years old) in the Selway-Bitterroot, duff was the heaviest fuel category; duff depths were 1.5 and 3.0 inches, and duff

Figure 29—Vegetation and fuels in Fire Group Seven. A. Stand 7A, ABGR/XETE-VAGL habitat type on gentle, south-facing slope in Priest Lake District, Kaniksu National Forest. Dense, pole-sized lodgepole pine dominate, with sparse grand fir understory. B. Stand 7B, ABGR/CLUN-PHMA habitat type on southeast-facing bench in Priest River Experimental Forest. Overstory contains scattered large grand fir, with occasional large ponderosa pine and western larch; understory contains lodgepole pine, grand fir, paper birch, and Engelmann spruce. C. Stand 7C, north-facing slope in Salmon District, Nez Perce National Forest. Dominated by medium-sized grand fir; contains a few very large ponderosa pine. Sparse understory contains grand fir. Photo by Jim Mital. D. Stand 7D, ABGR/CLUN-CLUN habitat type on northeast-facing slope in Fernan District, Coeur d'Alene National Forest. Medium-sized grand fir dominate. E. Stand 7E, ABGR/ASCA-ASCA habitat type in Grand Fir Mosaic on moist, east-facing slope in Selway District, Nez Perce National Forest. Grand fir dominates all canopy layers.

Table 29—Conditions defining stands in the Grand Fir Mosaic Ecosystem (Ferguson 1991).

Condition	Characteristics of Grand Fir mosaic ecosystem
Habitat type	ABGR/ASCA, ABGR/SETR, ABLA/STAM, THPL/ASCA, or TSME/STAM
Elevation	4,200 to 6,000 feet
Tree species	Usually absent: lodgepole pine, western larch, Douglas-fir
Understory species	*Actaea rubra* well represented (cover ≥5 percent) or *Synthyris platycarpa* present Absent: *Cornus canadensis, Pyrola asarifolia, Pyrola picta,* & *Vaccinium scoparium*

loadings were estimated to be 30 and 59 tons per acre (Habeck 1985). Downed woody fuels averaged 24.4 tons per acre on two Group Seven sites measured by Walker (1973) in the Selway-Bitterroot. On similar sites in Montana, total woody fuel loadings ranged from 12.8 to 38 tons per acre, with duff depths of 1.8 to 4.0 inches (Fischer 1981a,b). Most of the downed woody fuel results from accumulated deadfall and natural thinning, but grand fir also produces a relatively heavy load of twigs and small branchwood. Precommercial thinning in northern Idaho, in grand fir stands with average tree diameters of 1 to 2 inches, increased fuel loadings by 5.1 to 19.2 tons per acre (Koski and Fischer 1979).

Variety in stand structure and fuel arrays in Fire Group Seven can be seen in figure 29. Downed snags from a previous fire account for most of the woody fuels in Stand 7A (fig. 29). Stands 7B and 7D have debris on the forest floor and also vertically suspended in tree regeneration. Regeneration and suspended woody fuels form fuel ladders into the tree crowns, enhancing the potential for crown fire, if ignition occurs. The understory in Stand 7B is dominated by seral trees, which may have originated after a patchy burn that thinned overstory trees and created small openings. Heavy woody fuels occur in Stand 7C (table 30). Stand 7E is on a very moist site in the Grand Fir Mosaic. Woody fuels are protected from drying by a lush understory.

Large, severe fires can occur in Group Seven forests during droughts, killing most trees in mature stands. Even moist sites are vulnerable because they are usually small or narrow. Where Group Seven stands occur in a thermal belt (see discussion in "Role of Fire" in Group Eight), on mid-slope positions, and on slopes perpendicular to dominant storm tracks, the likelihood of ignition and severe fire is increased (Barrett 1982; Fowler and Asleson 1984; Larsen and Delavan 1922). Barrows (1951) noted a belt of very high fire occurrence (116 lightning ignitions per million acres per year) between 5,000 and 7,000 feet elevation.

Fire behavior is related to stand structure as well as climatic conditions. Stands with openings and those with ample moisture support dense herbs and shrubs,

Table 30—Stand characteristics and fuel loadings for some Group Seven stands. Fuel loadings are in tons/acre. Stand 7C is shown in figure 29. Stand 7F, in the St. Maries District, Coeur d'Alene National Forest, is dominated by medium-sized Douglas-fir and grand fir; understory contains grand fir, Douglas-fir, and Engelmann spruce. Stand 7G, in Elk City District, Nez Perce National Forest, is on a southwest-facing slope at 6,254 feet elevation. Dominant trees are medium-sized. Grand fir and subalpine fir comprise understory. (Data were provided by Jim Mital and are on file at Intermountain Fire Sciences Laboratory, Missoula, MT.)

						Dead and down load by size class (inches)					Total dead and down load
Stand No.	Habitat type-phase	Age	Tree spp.	Canopy cover	Litter, duff depth	0-¼	¼-1	1-3	3+ sound	3+ rotten	
		Years		*Percent*	*Inches*	*Tons per acre*					
7C[a]	ABGR/LIBO-LIBO	100	ABGR	98	1.7	0.1	1.8	1.9	0.8	10.2	14.8
			PIPO	3							
7F	ABGR/CLUN-CLUN	65	PSME	50	2.9	0.1	1.0	4.6	0.0	0.0	5.7
			ABGR	40							
			LAOC	3							
7G	ABGR/XETE-VAGL	95	ABGR	70	0.5	0.1	0.5	0.7	0.0	0.0	1.3
			PICO	30							
			PSME	20							

[a]Refers to stand number in text.

which impede drying. The closed canopy of mature forests keeps fuels moist during most summers, but dense structure and ladder fuels can enhance fire spread during drought. *Taxus brevifolia* stands and wet plant communities, especially in the ABGR/SETR habitat type, may retard or stop fire spread (Crawford 1983; U.S. Department of Agriculture, Forest Service 1992). Fuels dry slowly in Grand Fir Mosaic stands, and Mosaic forests occasionally interrupt the spread of large fires (Ferguson 1991).

Severe, stand-replacing fires do not consume all of the duff and woody fuels on Group Seven sites; fuels in a stand opened by fire dry more quickly during the following years and so may be subject to severe reburns.

Role of Fire

Fire Group Seven may have the most variable fire regime in northern Idaho, ranging from frequent severe burns that are followed by persistent shrubfields to areas in the Grand Fir Mosaic, where evidence of historic fire is difficult to find.

The most severe fire regime documented for Fire Group Seven occurs near Cook Mountain, in the Clearwater National Forest (Barrett 1982). The mean interval between severe fires for grand fir habitat types in this area was 29 years, with intervals in individual stands ranging from 9 to 78 years (table 31). Historic fires in the Cook Mountain area reached their peak severities at middle elevations, especially on south and west aspects (Barrett 1982). Nonlethal surface fires occasionally burned through forests on north-facing slopes (one to four per century). The history of frequent, severe fires in the Cook Mountain area has resulted in slow, erratic forest regeneration. Barrett (1982) described stands in the grand fir series that burned two to five times between 1869 and 1919. Forest recovery was best on north-facing slopes, with canopy cover in 1981 averaging 60 percent, but highly variable. Western larch and lodgepole pine were the

Table 31—Presettlement fire regimes for Fire Group Seven habitat types in northern Idaho. Locations of studies are shown in figure 1. Fire interval range lists minimum and maximum individual intervals from the study area. Mean fire interval and standard deviation (s.d.) are computed from stand mean fire intervals for the study area.

Location, habitat types, cover	Fire severity	Years: Fire interval range	Years: Mean fire interval	Years: S.d.	Number of stands
N. Fork Coeur d'Alene R[a]:					
—Interior (TSHE,ABGR series)	Stand replacing	18 to 452	203	82	
	All fires		84	45	
—near Rathdrum Prairie	Stand replacing		138	51	
(TSHE,ABGR,PSME series)	All fires		62	31	
N. Fork Clearwater R. basin[b]: ABGR/CLUN,/ASCA					
—steep slopes	Mainly lethal	109+ to 278+	185+		3
Clearwater N.F., Cook Mtn.[c]:					
—PSME & ABGR series, mostly shrubfields	Mostly lethal underburns and crown fire	9 to 78	29	11	7
Selway Ranger District, Nez Perce National Forest[d]: ABGR/ASCA					
—Grand fir, Engelmann spruce cover	Mixed		29		1
Selway-Bitterroot Wilderness[e]:					
ABGR/ASCA,/CLUN,/LIBO	Lethal		119		13
	Mixed		50 to 100		
S. Fork Clearwater R. basin[b]: ABGR/CLUN,/XETE					
—PIPO-PSME-ABGR cover	Nonlethal and mixed	25 to 67	45	17	4
—PSME-ABGR cover	Mixed and lethal	74 to 191+	116+		2

[a]Zack and Morgan (1994b). Includes stands in both Fire Group Seven and Fire Group Eight. Intervals for full study (1540-1992) are presented here. For presettlement times, average intervals between lethal fires were slightly greater; average intervals between all fires were slightly smaller.
[b]Barrett (1993). "+" indicates fire interval was incomplete at time of study but its inclusion did not shorten mean.
[c]Barrett (1982). Includes stands in both Fire Group Two and Fire Group Seven.
[d]Green (1994).
[e]Barrett and Arno (1991), Brown and others (1994, 1995).

most successful invaders; western white pine was a successful pioneer species on similar sites prior to its decimation by white pine blister rust. Large expanses of south- and west-facing slopes in the Cook Mountain area were still covered by shrubfields in 1981. (For further discussion, see "Persistent Seral Shrubfields.")

Most presettlement fire regimes in Group Seven consisted of lethal burns and mixed-severity fire (table 31). Average intervals between lethal fires ranged from 119 years in the Selway-Bitterroot Wilderness (Barrett and Arno 1991) to 203 years in the Coeur d'Alene River basin, where Group Seven and Group Eight stands are intermixed (Zack and Morgan 1994b). Where fires were infrequent and severe, a mixture of Douglas-fir and grand fir was favored (Barrett 1993). In the North Fork Clearwater River basin, single-age stands indicate a history of severe fire; most fire scars are found along the margins of old burns rather than in areas where nonlethal or mixed-severity fire was extensive (Barrett 1993). Similar habitat types in the South Fork Clearwater River basin have a history of nonlethal fire that has favored ponderosa pine.

The fire history of the North Fork Coeur d'Alene River basin illustrates the potential for neighboring stands to influence fire regimes. Presettlement intervals between fires in the continuously forested interior of this area are significantly longer than intervals in stands near the edge of the Rathdrum Prairie, a grassland probably maintained in presettlement times by frequent fire (Zack and Morgan 1994b).

Fire regimes shape Group Seven forests in a complex interaction with insects and disease. Low- and mixed-severity fires increase structural complexity within stands and heterogeneity across the landscape. Low-severity fires often damage the boles of Engelmann spruce, fir, western white pine, and lodgepole pine, forming entry points for decay organisms. Species with thicker bark (Douglas-fir, western larch, and ponderosa pine) are thus favored. Severe fire eventually disrupts mature stands, usually leading to vigorous regeneration. Douglas-fir and Engelmann spruce become established, mixed with western larch, western white pine, ponderosa pine, or lodgepole pine. The latter species are relatively resistant to defoliating insects and root disease (Byler and others 1994). As the forest matures, pines are thinned or removed by bark beetles; diseased western white pines are especially susceptible (Kulhavy and others 1984). Without low- or mixed-severity fire, Douglas-fir and grand fir increase, accompanied by increasing stress from defoliating insects and root disease. Root disease is particularly widespread in the relatively dry habitat types of Group Seven (Williams and Marsden 1982). Root disease-caused mortality may increase dead and downed woody fuels in mature stands and thus increase potential fire severity. However, severe root disease centers stagnate in the stand initiation stage (Byler and others 1994); on these sites, heavy fuel accumulations are unlikely.

Since Grand Fir Mosaic sites stay cooler and more moist than non-Mosaic sites throughout the growing season, fuels also remain moist and thus reduce the potential for large or severe fire. Although Mosaic sites experience lightning strikes, few have resulted in large wildfires. Many stands are old, with diameter distributions that indicate an uneven age structure. Seral species may be poorly represented because fire-free intervals on Mosaic sites are often longer than the average lifespans of seral tree species (Ferguson 1991). Lodgepole pine, ponderosa pine, and western larch are present on very few Mosaic sites; Douglas-fir and western white pine occur infrequently.

Forest Succession

Several studies describe the composition and structure of seral stands in Fire Group Seven, but successional pathways have not been thoroughly described. Habeck (1985) compared early with late seral stands in the ABGR/CLUN habitat type in the Selway-Bitterroot Wilderness. Green and Jensen (1991) and Green (1992) described seral stands that are typical of various site conditions in the ABGR/ASCA habitat type, Nez Perce National Forest (table 32). Some information on succession is available from areas adjacent to northern Idaho. Antos and Habeck (1981) described succession for grand fir stands in western Montana (mostly in the ABGR/CLUN habitat type) containing western larch, lodgepole pine, Douglas-fir, and some western white pine. Steele and Geier-Hayes (1987) described successional stands in the ABGR/VAGL habitat type, an incidental habitat type in northern Idaho (Cooper and others 1991). Our descriptions of succession are based on these studies, the species composition of mature Group Seven stands (Cooper and others 1991), and the autecological characteristics of dominant tree species.

Some herbaceous species are abundant only in early succession in Fire Group Seven. Humphrey and Weaver (1915) described abundant *Epilobium angustifolium* on a 25 year old burn in the Idaho portion of the Bitterroot National Forest. In the ABGR/CLUN habitat type in the Selway-Bitterroot Wilderness, *Epilobium angustifolium*, *Iliamna rivularis*, *Centaurea maculosa*, and *Hypericum perforatum* (an introduced species) occurred in a 15 year old stand but not in a 185 year old stand (Habeck 1985). *Ceanothus velutinus*, germinating from soil-stored seed, can dominate ABGR/CLUN stands within 8 years of wildfire (Zamora 1975). Shrub cover increases until maximum cover is reached (usually in 20 to 30 years), or until tree cover becomes dominant (Mueggler 1965). Herb and shrub

Table 32—Trees and shrubs characteristic of succession in the ABGR/ASCA habitat type (Green 1992). Data are on file at the Intermountain Fire Sciences Laboratory, Missoula, MT.

Phase of ABGR/ ASCA	Site conditions	Fire history: Time since burn	Fire history: Probable fire intensity	Tree species in seral stands[a]	Major[b] seral shrub species
		Years			
ASCA	Low elevation, dry	50-100	High	PSME,ABGR,LAOC = PIMO	ACGL,LIBO,SYMO
ASCA	Dry; sandy substrate	50-100	High	PSME,ABGR,PIEN	LIBO,VAGL
ASCA	Cold, dry	60- 70	High	PSME,PIEN,ABGR,ABLA	VAGL
ASCA	Moist	100-170	Mod-high	ABGR,PSME	MEFE,ACGL,PHMA,VAGL
		100-170	Mod-high	ABGR,LAOC = PIEN,PSME	(none listed)
MEFE	Dry	60-100	Mod-high	ABGR,PSME,PIEN	VAGL,MEFE,LIBO
MEFE	Cold	100-150	Mod-high	PSME,PIEN = ABGR	MEFE = VAGL
MEFE	Moist	100-160	Mod	ABGR,PSME	ACGL,VAGL,MEFE,AMAL = PAMY = RUPA
		80-120	Mod-high	PIEN,ABGR,PSME	MEFE,LOUT = VAGL
		50-100	Low-mod	ABGR,PIEN	MEFE,VAGL
		30- 50	Low-mod	(none listed)	VAGL,ACGL,PHMA = RUPA = SASC = SOSC
TABR		100-150	Mod-high	ABGR,PIEN	TABR,ACGL,VAGL,LIBO

[a] Listed according to average percent cover, from high to low.
[b] Species with average cover of 3 percent or more; TABR is classified as a shrub in this table.

composition changes dramatically when the tree canopy closes (Antos and Habeck 1981; Habeck 1985). Mueggler (1965) listed herb and shrub species likely to increase and decrease after fire in stands of Fire Groups Seven and Eight in northern Idaho (table 33). Canopy closure can begin and tree regeneration rates decline as early as 15 years after fire (Wellner 1940). Severe fire or reburns, however, can prolong shrub dominance for a century or more (Barrett 1982), during which isolated trees (Douglas-fir, Engelmann spruce, grand fir, and western white pine) may slowly become established (Antos 1977).

Successional pathways for Fire Group Seven vary. Douglas-fir, the most common seral species (Cooper and others 1991), occurs in a mixture that may include ponderosa pine, western larch, western white pine, lodgepole pine, and Engelmann spruce. Grand fir may also occur early in succession. This complex, variable

Table 33—Herbs and shrubs that are likely to decrease significantly or increase significantly after severe fire (Mueggler 1965). "Seral" stands were observed 2 to 60 years after fire; some had been both logged and burned. Habitat types probably included ABGR/CLUN, THPL/CLUN, THPL/ASCA, TSHE/CLUN, TSHE/ASCA, and TSHE/GYDR.

	Lower cover or frequency in seral stands		Higher cover or frequency in seral stands	
Shrubs	*Lonicera utahensis*		*Alnus sinuata*	*Prunus emarginata*
			Ceanothus sanguineus	*Rubus parviflorus*
			Ceanothus velutinus	*Salix scouleriana*
			Pachistima myrsinites	*Spiraea betulifolia*
Herbs	*Adenocaulon bicolor*	*Pyrola secunda*	*Achillea lanulosa*[a]	*E. angustifolium*
	Asarum caudatum	*Senecio serra*	*Aster conspicuus*[a]	*Solidago* spp.[a]
	Bromus vulgaris	*Smilacina stellata*	*Calamagrostis rubescens*[a]	*Trifolium* spp.[a]
	Chimaphila spp.	*Streptopus amplexifolius*	*Carex* spp.	
	Clintonia uniflora	*Thalictrum occidentale*		
	Coptis occidentalis	*Tiarella trifoliata*		
	Goodyera oblongifolia	*Trillium ovatum*		

[a] More abundant on reburned sites than on sites burned only once.

pattern is described in Pathway 7.1. On moist sites in Fire Group Seven, including the Grand Fir Mosaic, grand fir and Engelmann spruce dominate throughout succession (Pathway 7.2). Group Seven sites with relatively cold conditions may be dominated in early succession by nearly pure stands of lodgepole pine; this pattern is described in Pathway 7.3. The successional pathways described here are qualitative guides. Since stand development varies with seed source, presence and vigor of pathogens, and disturbance history, actual succession on a given site may follow a path intermediate between or diverging from those described here.

Pathway 7.1. Succession Dominated by Douglas-fir and Other Seral Species—After severe fire, a stand in this pathway is quickly dominated by forbs and grassy species (fig. 30 A). (Subsequent references in this section are to fig. 30.) Within 8 to 10 years, shrubs dominate.

Tree regeneration is dominated by Douglas-fir, but includes many other species (B). Western white pine was a common seral species prior to the advent of white pine blister rust. In mixed-species stands, western white pine often overtopped competitors about 40 years after disturbance. Where western white pine was dominant, Douglas-fir declined after about 40 years because of root disease, and western larch declined after about 70 years because of competition (Hagle and others 1989). After crown fires on stands in the grand fir series, Clearwater National Forest, Barrett (1982) found western larch, lodgepole pine, and Douglas-fir prevalent on west-facing slopes; western larch dominance was less on south-facing slopes, and Douglas-fir dominance was greater. Where severe fire occurs before western larch have developed thick bark and are old enough to produce seed, ponderosa pine and lodgepole pine may be favored. Ponderosa pine is common on warm sites, especially those with a history of low-severity fire. Lodgepole pine and Engelmann spruce are favored by cool conditions. Grand fir and subalpine fir may establish along with shade-intolerant species, but in this pathway they do not dominate until late succession.

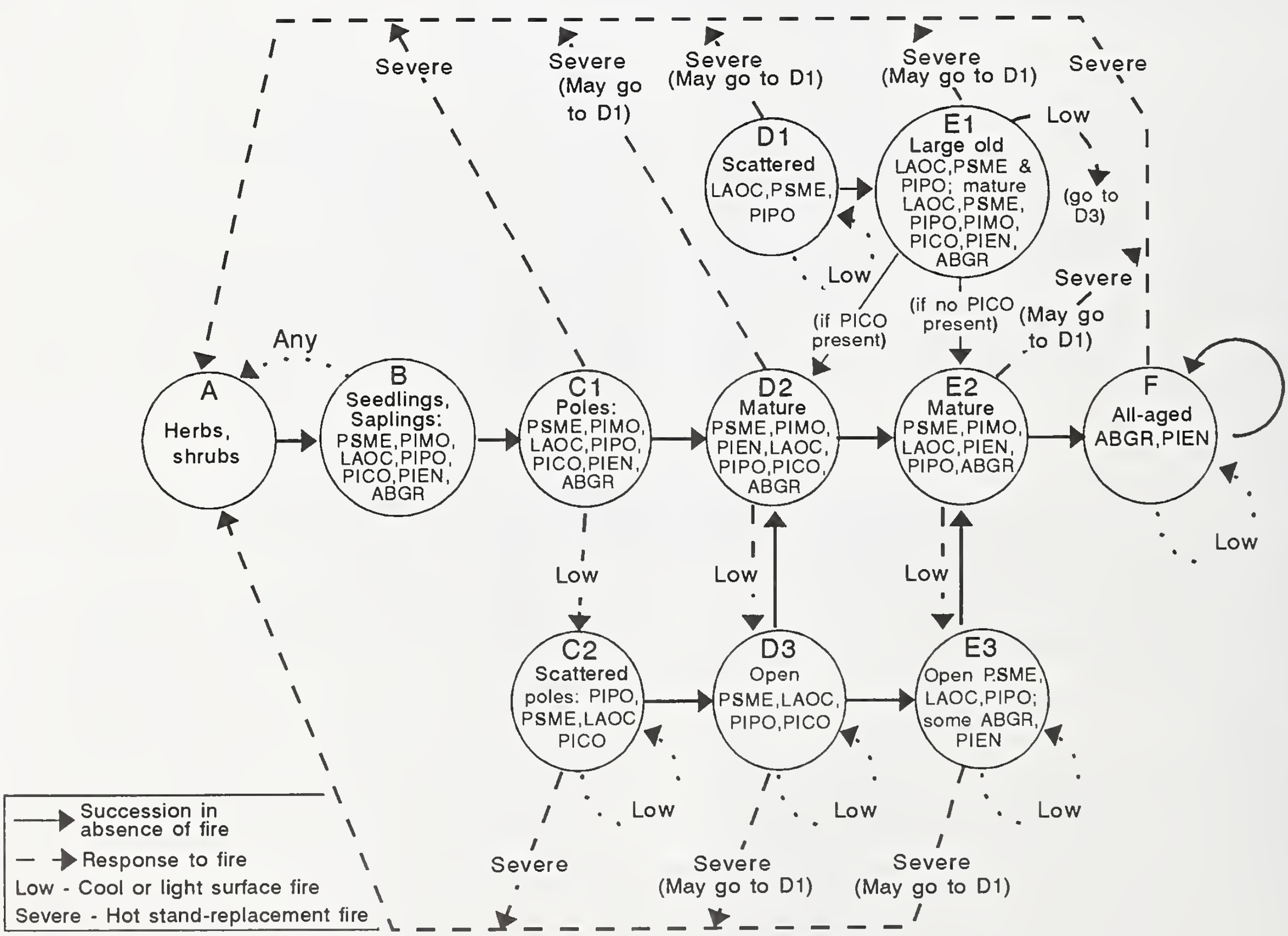

Figure 30—Pathway 7.1. Hypothetical fire-related succession for Fire Group Seven sites where succession is dominated by Douglas-fir and other seral species.

During the pole stage (C1), ponderosa pine is the most fire-resistant species. If present, it is favored by low-severity fire. Scattered Douglas-fir, western larch, and lodgepole pine can also survive. Thus, low-severity fire produces a very open stand and eliminates Engelmann spruce, grand fir, and western white pine (C2).

As stands mature without fire (D2), all trees develop some fire resistance. Low-severity fires remove most of the spruce, grand fir, and western white pine (D3). Species composition of regeneration depends on seed source, size of openings, and soil surface conditions. Severe fires often return the site to herbs and shrubs (A). However, mature western larch can withstand even severe fire, as can some Douglas-fir and ponderosa pine; therefore, clusters of relict trees often occur on sites sheltered from extreme fire behavior by topographic features (D1). Seedlings from relict trees usually dominate regeneration (E1). Many western larch 8 inches d.b.h. and larger survived a severe burn in Group Seven and Eight stands in the Idaho portion of the Bitterroot National Forest; 25 years later, regeneration was dominated by a mixture of western larch and grand fir (Humphrey and Weaver 1915).

Lodgepole pine dies out at about 100 to 160 years of age (E2). Because Douglas-fir, western larch, and western white pine continue vigorous growth as mature trees, they can continue to dominate even though they do not reproduce under the closed canopy (Antos and Habeck 1981). Mountain pine beetle may thin western white pine after about 100 years (Hagle and others 1989). Low-severity fire at this stage favors Douglas-fir, western larch, and ponderosa pine (E3). Severe fire returns the site to herbs and shrubs (A), or produces stands dominated by relict trees (D1). Lodgepole pine may be poorly represented in regeneration because of lack of seed.

Without disturbance, species dominance gradually shifts from Douglas-fir and other seral species to grand fir (F). Ponderosa pine, western larch, and western white pine persist because of their longevity, but they do not regenerate in the mature stand. If fire is excluded for two to three centuries, these species decline, leaving an old-growth stand of grand fir and scattered Engelmann spruce. Very low-severity fires alter these stands very little; more severe fires return them to herbs and shrubs (A).

Pathway 7.2. Succession Dominated by Grand Fir and Engelmann Spruce—On moist sites in Fire Group Seven (for example, the ABGR/ASCA-MEFE, ABGR/ASCA-TABR, and ABGR/SETR habitat types), and in the Grand Fir Mosaic, Engelmann spruce may be the only important seral species. On some sites, grand fir dominates throughout stand development (Cooper and others 1991; Ferguson 1991). This successional pathway has not been described in detail. Trees either regenerate soon after fire or more slowly, under the shelter of shrubs. On moist sites, grand fir and Engelmann spruce establish within 10 years, even in competition with the vigorous forb and shrub growth that follows fire. *Taxus brevifolia* becomes "well established" within 100 years of fire (Green 1992). Seral species other than spruce are well represented only on ridges and other relatively dry sites. Lodgepole pine may be reduced early in succession by heavy snow cover (Ferguson and Adams 1994).

Any fire during early succession returns the site to herbs and shrubs, with an increased probability of slow regeneration because of the loss of seed source and loss of decaying wood. Low-severity fire has little effect on overstory composition but alters stand structure, both through direct mortality and through fungi that invade fire-caused wounds. Where disturbances are severe or repeated, *Pteridium aquilinum* and *Rudbeckia occidentalis* can form a persistent, dense sward and delay tree regeneration (Ferguson and Boyd 1988).

Pathway 7.3. Succession Dominated by Lodgepole Pine—Cold sites in Fire Group Seven, especially on gentle topography where cold air pools, may be dominated in early succession by lodgepole pine. Stand 7A (fig. 29) is an example. This pathway is common in the ABGR/VAGL and ABGR/XETE habitat types, but can occur on other Group Seven sites characterized by cold conditions. In western Montana, the lodgepole pine pathway occurs in ABGR/CLUN stands perpetuated by stand-replacing fires at intervals of 100 to 150 years (Antos and Habeck 1981). According to the description of seral ABGR/VAGL stands in central Idaho (Steele and Geier-Hayes 1987), lodgepole pine dominance gives way "in a relatively short time" to dominance by Douglas-fir, Engelmann spruce, grand fir, or a mixture of these species. Because of the similarity of this pattern to that of seral lodgepole pine in the subalpine fir series in northern Idaho, the reader is referred to Pathway 4.2 (fig. 22); replace references to subalpine fir with grand fir.

Fire Management Considerations

The degree to which Group Seven stands have been affected by fire exclusion is related to geographic area and local environment, but it is not closely linked to habitat type. All of the fire regimes described in table 31, with the possible exception of those at Cook Mountain (Barrett 1982), are from areas mostly in the ABGR/CLUN and ABGR/ASCA habitat types. In the South Fork Clearwater drainage, where low- and mixed-severity fire was common in presettlement times, fire exclusion has led to the development of dense understory vegetation and loss of distinct seral age classes (Barrett 1993). Recent spring underburns

have failed to reduce fuels substantially. Barrett (1993) recommended "aggressive" fuel reduction to reduce potential wildfire severity and enable managers to base future management programs on presettlement fire regimes. In the Selway-Bitterroot Wilderness and the North Fork Clearwater River drainage, stand-replacing fire dominated presettlement fire regimes (Barrett 1993; Brown and others 1994). Current stand ages in many areas exceed the longer fire-free intervals that occurred in presettlement times. But the effects of fire exclusion are subtle, including increased homogeneity in large stands and loss of nonlethal fire effects near margins of severe burns. In moist Group Seven stands on gentle topography, including stands in the Grand Fir Mosaic, fires were seldom extensive in presettlement times. Fire exclusion removes a source of small-scale disturbance in these moist forests and may reduce opportunities for seral species to regenerate on well-drained sites and ridges (Green 1994).

Changes caused by fire exclusion from moderate Group Seven stands have been exacerbated by the decline of western white pine as an important seral species (Ferguson 1994). Although fire can be used to create opportunities for seral species to establish, western white pine would have to be planted because rust resistance in natural seed sources is extremely limited. Since *Ribes* species often increase after disturbance on mesic sites, rust-resistant varieties of western white pine would be required.

Fire is used in Fire Group Seven to reduce fuel loadings and fuel continuity, enhance wildlife habitat, and favor seral species in tree regeneration. Underburning can be used where seral species still dominate to reduce fuels and duff and to enhance opportunities for regeneration by seral species. Because of dense ladder fuels and heavy surface fuels, mechanical thinning or repeated underburns are usually needed to meet objectives (Barrett 1982, 1993; Kilgore and Curtis 1987). To use fire for duff reduction on north-facing slopes with high fuel loadings, Kilgore and Curtis (1987) recommended an initial low-severity underburn, followed by harvesting and possibly thinning, and then a second underburn to reduce activity fuels. Simmerman and others (1991) pointed out that stress from prolonged competition in pretreatment stands can contribute to high post-treatment mortality in seral species from windthrow, insects, and disease. Delayed mortality in damaged firs may be very high due to fungal infection (Kilgore and Curtis 1987).

Large mammals use Group Seven sites at various stages of succession. Elk and deer use the ABGR/ASCA-ASCA and ABGR/CLUN habitat types for summer range; they also use low-elevation, south-facing sites in early succession (dominated by shrubs) as winter range (Cooper and others 1991). Bear use shrubfields during late summer and fall, especially where *Vaccinium* and *Sorbus scopulina* are abundant (Steele and Geier-Hayes 1987). Shrub development after fire can be very rapid. Five years after a severe wildfire on a previously harvested Group Seven stand in the Coeur d'Alene National Forest, cover of *Ceanothus sanguineus* exceeded 70 percent (Drew 1967). *Ceanothus velutinus* peaked in productivity 8 years after treatment on clearcut, broadcast-burned ABGR/CLUN stands in the Clearwater District, Nez Perce National Forest (Zamora 1975); it was gone after 23 years, when other shrub species were still increasing in cover. The pattern of *Ceanothus* decline while taller shrubs continue to develop has also been reported in other northern Idaho studies (Irwin and Peek 1979; Wittinger and others 1977).

Aspect is a useful predictor of early seral species on Group Seven sites. *Amelanchier alnifolia*, *Carex rossii*, *Ceanothus velutinus*, *Ceanothus sanguineus*, *Fragaria* species, *Iliamna rivularis*, *Pteridium aquilinum*, and *Prunus emarginata* are common on south-facing slopes. *Alnus sinuata*, *Asarum caudatum*, *Coptis occidentalis*, *Menziesia ferruginea*, *Ribes viscosissimum*, *Rubus parviflorus*, *Sambucus racemosa*, and *Vaccinium* species are more prevalent on north-facing slopes (Mueggler 1965; Zamora 1975, 1982). Successional patterns on broadcast burned clearcuts are shown for some herbaceous species in figure 31.

Mesic sites in Fire Group Seven provide winter habitat for moose and are used heavily during summer and fall (Crawford 1983). Sites dominated by *Taxus brevifolia* are especially favored. *Taxus* is most vigorous and most dense in uncut stands. It can survive overstory removal, but is extremely vulnerable to fire. Crawford (1983) described a patchy broadcast burn in which *Taxus* trees survived only where the surrounding grass was unburned. *Taxus* may be totally lost from plots burned by severe fires. It survives only if burning is conducted late in the season and individual plants are protected (U.S. Department of Agriculture, Forest Service 1992).

Fire exclusion, selective harvesting of seral species, and white pine blister rust have reduced the number of conifers resistant to root disease in Fire Group Seven (Harvey and others 1994; Thies and Sturrock 1995). Recommendations for ecological restoration and sustainable timber production on moderate Group Seven sites include partial and regeneration cutting, and regenerating with seral species (Byler and others 1994). Seedtree and shelterwood treatments produce more successful regeneration than clearcuts on severe sites such as south- and west-facing slopes (Ferguson and Carlson 1991; Ferguson and others 1986). Standing snags can provide shelter for regeneration (Antos and Shearer 1980). To regenerate north-facing slopes with western larch, seedtree cuts and even-age management have been recommended (Antos and Shearer 1980; Barrett 1982; Steele and Geier-Hayes 1987).

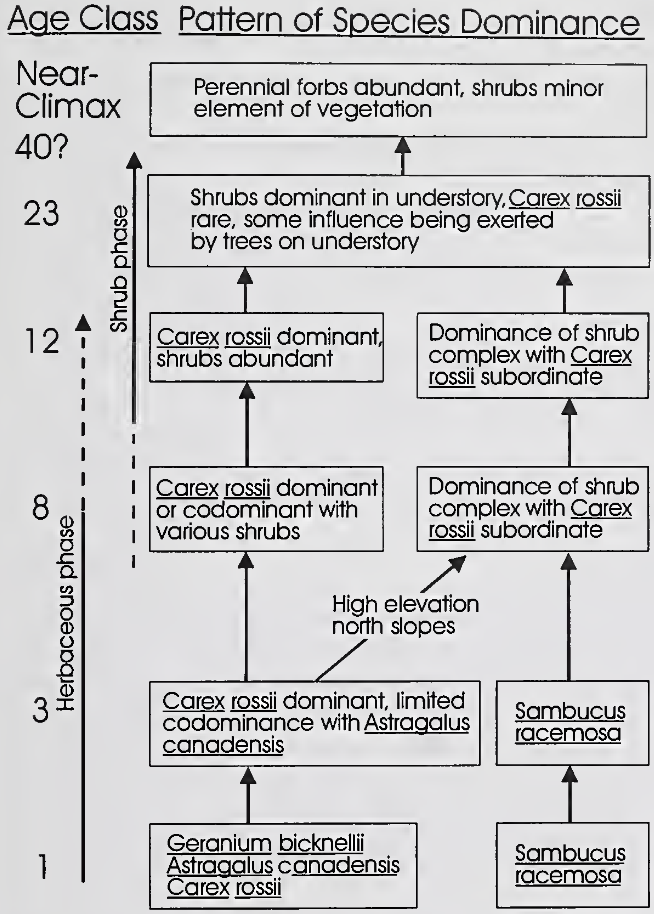

Figure 31—General features of early succession on clearcut, broadcast-burned sites in habitat types of the grand fir series, mainly ABGR/CLUN (Zamora 1975). Species names in boxes represent the most commonly occurring dominants. The width of each box represents tne proportion of the total stands in each age class in which the species were dominant.

Rapid postfire shrub development can compete severely with tree regeneration in Fire Group Seven. Planting provides a 1 to 2 year lead over natural regeneration where shrub competition is intense (Shearer 1982). If shrub competition is very severe, planting of shade-tolerant species may be the only means to accelerate reforestation; natural regeneration of grand fir grew faster than western white pine on ABGR/CLUN stands in the Deception Creek Experimental Forest where *Ceanothus velutinus* cover was dense (Boyd 1969).

Fire is used on moderate Group Seven sites for slash reduction and site preparation. Mineral soil exposure enhances regeneration by shade-intolerant species (Ferguson 1994), especially where Engelmann spruce has been dominant (Steele and Geier-Hayes 1987). Woody debris must be conserved, however. Graham and others (1994) recommended leaving 7 to 14 tons per acre of woody debris larger than 3 inches in diameter after harvesting ABGR/XETE stands in the Lolo National Forest, MT. Burning generally produces fewer seral herbs and more shrubs than scarification, an advantage for regenerating relatively dry stands that are likely to be invaded by pocket gophers (Steele and Geier-Hayes 1987). For ABGR/ASCA sites in the Nez Perce National Forest, Green (1992) recommended basing site preparation and regeneration on habitat type phase, site type, and pretreatment species composition (table 34). Evaluation of the potential for *Pteridium aquilinum* and *Rudbeckia occidentalis* to expand and inhibit tree regeneration is very important (Green 1992; Zamora 1975). After shelterwood cutting on sites in Fire Groups Three, Seven, and Eight on the Priest River Experimental Forest, underburning was the optimum treatment for obtaining regeneration (Simmerman and others 1991). Ponderosa pine and western larch germinated three to 12 times more successfully on burned plots than on unburned plots. The germination rates on burns conducted under dry conditions (0-1 inch fuel moisture 11 percent, duff moisture 35 to 41 percent) were double those on sites burned under moist conditions (0-1 inch fuel moisture 10-14 percent, duff moisture 88-91 percent).

In the Grand Fir Mosaic and other moist Group Seven stands, fire may be useful for raising soil pH to enhance establishment of some shrubs and seral trees (Ferguson 1993). Since moist Group Seven sites do not burn readily, burning for fuel reduction may not be warranted when weighed against some advantages of minimizing disturbance:

1. Woody debris is left intact.
2. *Pteridium aquilinum* and *Rudbeckia occidentalis* have little potential to expand.
3. Pocket gopher expansion is not encouraged.
4. Residual trees are not damaged by fire and thus their susceptibility to infection by Indian paint fungus is not increased.
5. Advance regeneration is left intact.
6. Watershed integrity is protected in areas with characteristically very deep snowpack.

Advance regeneration on moist Group Seven sites consists of grand fir, subalpine fir, and Engelmann spruce. On moist sites, where these species probably dominated throughout stand development in presettlement times, they are often the species best suited for regeneration. Green (1992) recommended regenerating with grand fir and Engelmann spruce on moist site types in the ABGR/ASCA habitat type (table 34).

Table 34—Recommended silvicultural procedures to successfully regenerate harvested sites in the ABGR/ASCA habitat type in the Nez Perce National Forest (Green 1992). Information is on file at the Intermountain Fire Sciences Laboratory.

Phase of ABGR/ASCA habitat type	Site type or description	Other pre-treatment considerations	Recommended procedures
ASCA	Dry	—	Light to moderate broadcast burn or light scarification. Minimize grass seeding. Consider gopher control.
ASCA	Moist	Expansion of *Pteridium aquilinum* and *Rudbeckia occidentalis* likely.	Light to moderate broadcast burn. Consider gopher control.
		Expansion of *Pteridium aquilinum* and *Rudbeckia occidentalis* unlikely.	Broadcast burn.
MEFE	Dry	High shrub density likely.	Broadcast burn and plant shade-tolerant species.
		Low shrub density likely.	Scarify and regenerate with PICO or PSME.
MEFE	XETE, cold	—	Burn and plant PIEN.
MEFE	Moist	—	Minimize disturbance, use small openings, plant shade-tolerant species.
TABR	—	High shrub density likely.	Manage for ABGR and PIEN.
		Low shrub density likely or site relatively dry.	Broadcast burn, manage for LAOC, PICO, PIMO, or PSME.

Fire Group Eight: Moderate and Moist Western Hemlock and Western Redcedar Habitat Types

Thuja plicata/Asarum caudatum h.t. - *Asarum caudatum* phase (THPL/ASCA-ASCA), western redcedar/wild ginger - wild ginger phase*#

Thuja plicata/Asarum caudatum h.t. - *Menziesia ferruginea* phase (THPL/ASCA-MEFE), western redcedar/wild ginger - menziesia phase+#

Thuja plicata/Asarum caudatum h.t. - *Taxus brevifolia* phase (THPL/ASCA-TABR), western redcedar/wild ginger - Pacific yew phase#

Thuja plicata/Clintonia uniflora h.t. - *Clintonia uniflora* phase (THPL/CLUN-CLUN), western redcedar/queencup beadlily - queencup beadlily phase*

Thuja plicata/Clintonia uniflora h.t. - *Menziesia ferruginea* phase (THPL/CLUN-MEFE), western redcedar/queencup beadlily - menziesia phase*+

Thuja plicata/Clintonia uniflora h.t. - *Taxus brevifolia* phase (THPL/CLUN-TABR), western redcedar/queencup beadlily - Pacific yew phase

Thuja plicata/Clintonia uniflora h.t. - *Xerophyllum tenax* phase (THPL/CLUN-XETE), western redcedar/queencup beadlily - beargrass phase

Thuja plicata/Gymnocarpium dryopteris h.t. (THPL/GYDR), western redcedar/oak-fern

Tsuga heterophylla/Asarum caudatum h.t. - *Aralia nudicaulis* phase (TSHE/ASCA-ARNU), western hemlock/wild ginger - wild sarsaparilla phase

Tsuga heterophylla/Asarum caudatum h.t. - *Asarum caudatum* phase (TSHE/ASCA-ASCA), western hemlock/wild ginger - wild ginger phase

Tsuga heterophylla/Asarum caudatum h.t. - *Menziesia ferruginea* phase (TSHE/ASCA-MEFE), western hemlock/wild ginger - menziesia phase

Tsuga heterophylla/Clintonia uniflora h.t. - *Aralia nudicaulis* phase (TSHE/CLUN-ARNU), western hemlock/queencup beadlily - wild sarsaparilla phase

Tsuga heterophylla/Clintonia uniflora h.t. - *Clintonia uniflora* phase (TSHE/CLUN-CLUN), western hemlock/queencup beadlily - queencup beadlily phase

Tsuga heterophylla/Clintonia uniflora h.t. - *Menziesia ferruginea* phase (TSHE/CLUN-MEFE), western hemlock/queencup beadlily - menziesia phase+

Tsuga heterophylla/Clintonia uniflora h.t. - *Xerophyllum tenax* phase (TSHE/CLUN-XETE), western hemlock/queencup beadlily - beargrass phase+

Tsuga heterophylla/Gymnocarpium dryopteris h.t. (TSHE/GYDR), western hemlock/oak-fern

* Likely to be maintained as persistent shrubfields, if burned by severe fire at intervals shorter than about 30 years.

May be in the Grand Fir Mosaic ecosystem; see table 29.

+ May be dominated in early succession by lodgepole pine.

Vegetation

Fire Group Eight includes most of the habitat types in the western hemlock and western redcedar series; sites are very productive and floristically diverse (fig. 32, table 35). Group Eight stands cover large areas in northern Idaho, particularly in the Idaho Panhandle National Forests. The habitat types of this fire group are common on northerly aspects at all slope positions and are found on southerly aspects where soils have favorable moisture-holding properties. Western hemlock habitat types are found only as far south as the North Fork Clearwater River. Western redcedar habitat types extend as far south as the South Fork Clearwater River, although large, continuous stands do not extend south of the Selway River drainage (Cooper and others 1991).

Up to 10 species of conifers may occur during succession in Group Eight stands—the two climax species (western hemlock and western redcedar) and eight seral species: western white pine, western larch, grand fir, Douglas-fir, subalpine fir, Engelmann spruce, ponderosa pine, and lodgepole pine. Ponderosa pine is a minor seral species occurring mainly in the THPL/CLUN and THPL/ASCA habitat types; lodgepole pine is important only in locations with very frosty conditions. Three deciduous species also occur in Fire Group Eight: black cottonwood, paper birch, and quaking aspen (Habeck 1972; Keown 1984; Mack and others 1978; Zack 1994). In the Kaniksu National Forest, these species may form a distinct seral stage (Zack 1994).

The decline of western white pine because of harvesting, mountain pine beetle, and white pine blister rust, and its failure to regenerate due to blister rust (Graham 1990) have severely altered ecosystems containing Group Eight stands. In the 1890's, western white pine comprised 33 percent of the trees in the Priest River Forest Reserve, including subalpine areas (Leiberg 1899b). In the 1980's, however, western white pine occurred in only 6 percent of plots used to describe the Group Eight habitat types (Cooper and others 1991). Figure 33 shows a mature western white pine stand photographed near Pierce, ID, in 1928; loss of such stands and poor western white pine regeneration have altered species relationships, stand development, and successional pathways in Fire Group Eight from their historic patterns (Byler and others 1994).

Fire Groups Seven and Eight contain the habitat types with the most diverse flora in northern Idaho (Cooper and others 1991). A list of important shrubs and forbs occurring in late-successional and climax stands (table 36) contains species indicative of both wet sites (for example, *Alnus sinuata*) and relatively dry sites (for example, *Xerophyllum tenax*). *Bromus vulgaris* is the only grassy species common in mature Group Eight stands (Shiplett and Neuenschwander 1994). Old growth stands, especially on moist sites, are characterized by a rich flora, diverse soils and microclimates, and a variety of structural components—often due to lightning strikes and patchy burns. The flora of seral stands in Group Eight is also very rich; herbaceous and shrub species that dominate in various successional stages are described in "Forest Succession."

Fuels

The productivity of Group Eight stands is reflected in relatively heavy fuels (table 35). On Group Eight stands in the Moose Creek drainage, Selway-Bitterroot Wilderness, dead and downed woody fuel loadings ranged from 18.3 to 47.4 tons per acre (Habeck 1973). Walker (1973) found similar loadings in two other cedar stands in the Selway-Bitterroot. Ninety percent of woody fuels may be more than 3 inches in diameter; often, more than half are rotten. A large proportion of grand fir and cedar in the overstory contributes to relatively heavy loads of twigs and branchwood (table 35). Brown and Bradshaw (1994) used a large (more than 3 inches in diameter) woody fuel loading of 42.8 tons per acre for the western redcedar fire regime type in the Selway-Bitterroot Wilderness. Duff loadings also tend to be heavy. The fuel model for the cedar fire regime type uses a duff loading of 34.6 tons per acre (Brown and Bradshaw 1994). In TSHE/CLUN stands in the Deception Creek Experimental Forest, average duff depth was 1.5 inches, but duff distribution was variable. Seven percent of plot area had no duff, and 23 percent had duff less than 0.4 inches deep; 14 percent, however, was covered with rotten wood that averaged 5.1 inches deep (Reinhardt and others 1989, 1991).

Despite heavy fuels, fire hazard remains low to moderate in Group Eight during most summers. Understory humidity is usually high (Larsen 1922); young stands and old, open stands support understory vegetation that may remain green throughout the

Figure 32—Vegetation and fuels in Group Eight stands. A. Stand 8A, dominated by western redcedar and very large grand fir, is located on a west-facing slope in the Avery District, St. Joe National Forest. B. Stand 8B, on a southwest-facing slope in the Bonners Ferry District, Kaniksu National Forest, contains a mixture of cedar and lodgepole pine. (Stands A and B are also described in table 35.) C. Stand 8C, in THPL/ASCA-ASCA habitat type, Powell District, Clearwater National Forest, is dominated by large cedar and grand fir. D. Stand 8D, northeast-facing TSHE/CLUN-CLUN stand in Priest River Experimental Forest, contains large cedar, hemlock, and grand fir. A few very large, fire-scarred western white pine also occur. E. Stand 8E, in the TSHE/CLUN-ARNU habitat type, Sandpoint District, Kaniksu National Forest, is dominated by medium-sized western larch, paper birch, and a few western hemlock. Smaller trees are hemlock. Photos A and B by Jim Mital.

Table 35—Stand characteristics and fuel loadings for some Group Eight stands. Fuel loadings are in tons/acre. Stands 8A and 8B are shown in figure 32. Stand 8F, on a northeast-facing slope in the Pierce District, Clearwater National Forest, has medium and large cedar and grand fir in the overstory; *Taxus brevifolia* dominates the understory. Stand 8G, in the St. Maries District, St. Joe National Forest, is dominated by medium sized trees; regeneration is all western hemlock and western redcedar. Stand 8H, in the Lochsa District, Clearwater National Forest, is dominated by medium and large cedar and Douglas-fir; regeneration is cedar. Stand 8I, in the Bonners Ferry District, Kaniksu National Forest, contains very large western white pines; western hemlock and western redcedar are present as regeneration and as medium and large trees. (Data were provided by Jim Mital and are on file at Intermountain Fire Sciences Laboratory, Missoula, MT.)

Stand No.	Habitat type-phase	Age	Tree spp.	Canopy cover	Litter, duff depth	Dead and down load by size class (inches) 0-¼	¼-1	1-3	3+ sound	3+ rotten	Total dead and down load
		Years		Percent	Inches	Tons per acre					
8A[a]	THPL/ASCA-ASCA	190	THPL	70	2.2	0.0	0.5	0.9	3.2	8.5	13.1
			ABGR	30							
			PIMO	10							
8B	TSHE/CLUN-CLUN	100	PICO	20	4.1	0.1	1.3	1.1	7.3	8.9	18.7
			THPL	20							
8F	THPL/GYDR	95	THPL	60	3.3	0.1	0.3	2.0	1.6	13.2	17.2
			ABGR	20							
8G	TSHE/CLUN-CLUN	110	THPL	58	6.2	0.1	1.3	1.9	5.0	10.1	18.4
			ABGR	30							
			TSHE	20							
			PSME	10							
8H	THPL/ASCA-ASCA	100	THPL	50	2.0	0.1	1.3	1.1	6.1	35.8	44.4
			PSME	10							
8I	TSHE/CLUN-XETE	175	TSHE	40	9.5	0.1	1.0	3.0	19.2	30.3	53.6
			THPL	20							
			PIMO	10							

[1]Refers to stand number in text.

Figure 33—Mature stand of western white pine near Pierce, ID, photographed in 1928 by K. D. Swan. Photo courtesy of USDA Forest Service, Region One.

summer. In old growth and where low-severity fires have occurred, tree crowns are high and ladder fuels sparse. *Taxus brevifolia* may form a dense shrub layer or an understory tree layer that is slow to burn. Under very dry conditions, however, duff and woody fuels become dry and herbaceous material cures out. Surface and ground fires may smolder for months, and severe fire behavior (surface and crown fire) becomes possible. Tree regeneration and lichen-covered branches on mature trees enhance the potential for crown fire.

Even severe fires seldom consume all the duff on Group Eight sites, and fire may increase downed woody fuels. Fuels in a stand opened by fire or other disturbance dry more quickly in subsequent years, so these stands may be subject to reburns with severe fire behavior.

Timber harvesting in Group Eight stands in northern Idaho increases woody fuel loadings, but the amount

Table 36—Understory species common in mature and late-successional Group Eight stands (Cooper and others 1991, Mueggler 1965, Shiplett and Neuenschwander 1994, Zack 1994). Many of these species are also common in seral stands (see "Forest Succession").

Common shrub species	Common forb species	
Acer glabrum	*Adenocaulon bicolor*	*Gymnocarpium dryopteris*
Alnus sinuata	*Anemone piperi*	*Osmorhiza chilensis*
Linnaea borealis	*Arenaria macrophylla*	*Pedicularis racemosa*
Lonicera utahensis	*Arnica cordifolia*	*Polystichum munitum*
Menziesia ferruginea	*Arnica latifolia*	*Pyrola asarifolia*
Pachistima myrsinites	*Asarum caudatum*	*Pyrola secunda*
Rosa gymnocarpa	*Chimaphila umbellata*	*Smilacina stellata*
Rubus parviflorus	*Clintonia uniflora*	*Streptopus amplexifolius*
Symphoricarpos albus	*Coptis occidentalis*	*Thalictrum occidentalis*
Taxus brevifolia	*Cornus canadensis*	*Tiarella trifoliata*
Vaccinium globulare	*Disporum hookeri*	*Trillium ovatum*
	Galium triflorum	*Viola glabella*
	Goodyera oblongifolia	*Viola orbiculata*
		Xerophyllum tenax

of increase varies; Morgan and Shiplett (1989) found increases after clearcutting in the Group Eight habitat types ranging from 2.3 to 74.3 tons per acre. Reinhardt and others (1991) found total dead and downed fuels ranging from 28 to 86 tons per acre on harvested TSHE/CLUN sites in the Deception Creek Experimental Forest. After prescribed burning, woody fuels still averaged 31 tons per acre. Precommercial thinning in western hemlock and western redcedar stands with average tree diameters of 1 to 2 inches increased dead and downed woody fuel loadings 3.4 to 42.2 tons per acre (Koski and Fischer 1979).

Role of Fire

Fire has played a part in the history of most Group Eight forests. All of the THPL/ASCA, THPL/CLUN, and THPL/GYDR stands sampled for development of the northern Idaho habitat types had either fire-scarred trees or charcoal in the upper soil horizons (Cooper and others 1991). Early in this century, western white pine dominated large areas of the area now in the Idaho Panhandle National Forests; Marshall (1927) commented that most of these stands originated after severe fires that occurred during relatively dry climatic periods. Stand-replacing fires probably occurred on Group Eight sites at average intervals of 200 to 250 years in presettlement times (table 37). However, the diverse species and structures of Group Eight stands indicate that presettlement fire regimes were highly variable. In the Selway-Bitterroot Wilderness and in interior areas of the North Fork Coeur d'Alene River basin, mean intervals between stand-replacing fires in presettlement times were about 200 years, but individual intervals as short as 18 years and as long as 452 years were recorded (Brown and others 1994; Zack and Morgan 1994b). Near the frequently burned grasslands of the Rathdrum Prairie, the average interval between stand-replacing fires was significantly shorter than that in the interior (Zack and Morgan 1994b). Fire return intervals shorter than 140 years favored dominance by western white pine, western larch, Douglas-fir, and grand fir (Shiplett and Neuenschwander 1994). Some of the longest historic fire return intervals on Group Eight sites probably occurred in THPL/ASCA-ASCA stands of the Grand Fir Mosaic Ecosystem, where fire return intervals may have been longer than the average lifespan of seral trees (Ferguson 1991). Intervals between stand-replacing fires on sites dominated by lodgepole pine were probably much shorter than the average, since lodgepole pines usually live less than a century in Fire Group Eight (Haig and others 1941).

Many Group Eight forests were characterized by mixed-severity fire regimes and small, nonlethal burns in presettlement times. Examples can be found throughout northern Idaho (table 37). Presettlement fires in the Selway-Bitterroot Wilderness and in the North Fork Clearwater River drainage tended to be uniformly severe on upland sites, but burned in patchy patterns, with variable severity, in the canyon bottoms (Barrett 1993; Brown and others 1994). In the Cook Mountain area of the Clearwater National Forest, where severe reburns have had long-term effects on drier habitat types, Barrett (1982) described grand fir and western redcedar trees that survived underburns and then succumbed to pathogens a few years later. Green (1994) described the mixed-severity fire regime in Group Eight stands of the Selway District, Nez Perce National Forest: "Within the

Table 37—Presettlement fire regimes for Fire Group Eight habitat types in northern Idaho. Mean fire interval and standard deviation (s.d.) are computed from stand mean fire intervals for the study area. Fire interval range lists minimum and maximum individual intervals from the study area. Locations of studies are shown in figure 1.

Location, habitat types, cover	Fire severity	Years: Fire interval range	Years: Mean fire interval	Years: S.d.	Number of stands
Priest River Basin[a]:					
—THPL/ASCA,/CLUN, TSHE/ASCA,/CLUN,/GYDR	Highly variable, depending on topography		50-150		
N. Fork Coeur d'Alene R.[b]:					
—Interior (TSHE,ABGR series)	Stand replacing	18 to 452	203	82	
	All fires	4 to 322	84	45	
—near Rathdrum Prairie (TSHE,ABGR,PSME series)	Stand replacing		138	51	
	All fires		62	31	
North Fork Clearwater R.[c]:					
—THPL/CLUN,/ASCA	Stand replacing	177+ to 363+	258+		8
	Nonlethal	42 to 186	132	63	4
Cook Mtn., Clearwater National Forest[d]:					
—THPL/ASCA,/CLUN; mostly shrubfields	Variable low to high within burns	5 to 174	48	20	11
Selway-Bitterroot[e]: —THPL/ASCA,/ATFI,/CLUN	Stand replacing, some mixed severity		197		9
Selway Ranger District, Nez Perce National Forest[f] THPL/CLUN-CLUN, THPL/ASCA-ASCA:					
—THPL-ABGR cover	Mixed		29		7
—THPL-ABGR cover with PIPO,PSME,LAOC	Mixed		34		7

[a]Arno and Davis (1980).
[b]Zack and Morgan (1994b). Includes stands in both Fire Group Seven and Fire Group Eight. Intervals for full study (1540-1992) are presented here. For presettlement times, average intervals between lethal fires were slightly greater; average intervals between all fires were slightly smaller.
[c]Barrett (1993). "+" indicates fire interval was incomplete at time of study but its inclusion did not shorten mean.
[d]Barrett (1982).
[e]Barrett and Arno (1991), Brown and others (1994, 1995). Includes stands in both Fire Group Eight and Fire Group Nine.
[f]Green (1994).

almost 300 years of fire chronology, large, severe fires occur much more rarely than small, patchy or less severe fires." Low-severity fire occurred two to three times as often as either moderate- or high-severity fire. Where several fire-scarred trees occurred within a single stand, the scars had often originated after different fires. In the Salmo Priest Wilderness, topography influenced fire regime; avalanche paths filled with *Alnus*, wet bottomland forests, and rocky subalpine terrain limited spread of presettlement fires (Arno and Davis 1980).

Historic descriptions of seral stands in northern Idaho also include evidence of mixed-severity fire regimes. Marshall (1928) described western white pine stands 275 to 400 years old in the Kaniksu National Forest that burned in two or more surface fires. Rapraeger (1936) described a western white pine stand adjacent to the Clearwater National Forest, probably in a western redcedar habitat type (Mital 1993), that burned severely at different times in several small patches and contained western white pines from 90 to 345 years old. Fire-scarred trees had considerable decay.

Even stand-replacing fires in Group Eight forests regularly left a few large surviving trees, which moderated climatic conditions and influenced species composition in the new stand. Western larch is the species that occurs most often in such relict stands (Daubenmire and Daubenmire 1968; Haig and others 1941; Larsen 1925; Marshall 1928). Occasional relict Douglas-fir and ponderosa pine also occur. These three species survive mainly because of their fire-resistant bark and because they developed high crowns in open stands under the influence of low-severity burns. Relict western redcedar also occur in Group Eight stands (Marshall 1928) because this species can recover following fire, even if only a narrow strip of cambium remains alive.

A "thermal belt" created by nighttime temperature inversions has influenced fire's role in many Group Eight forests. Hayes (1941) described the thermal belt in the Priest River Experimental Forest, where it includes habitat types in Fire Groups Eight (north-facing slopes) and Two (south-facing slopes) (Denner 1993). Temperature inversions occurred on more than 90 percent of nights from June through September. From July through September, the median nighttime temperature at the middle-elevation station exceeded the valley-bottom temperature by 15 to 18 °F. Temperature inversions influenced both relative humidity and fuel moisture. Nighttime humidities were lower and woody fuels were drier at middle elevations than in valley bottoms. Since fuels are dry and burning conditions abate little at night, historic fires in thermal belts may have been more frequent, more extensive, and more uniformly severe than fires at lower elevations. Thermal belt conditions often occur on slopes perpendicular to prevalent storm tracks, increasing the potential for severe fire (Fowler and Asleson 1984). Frequent and severe burns, especially on south- and west-facing slopes, have contributed to the persistence of seral shrubfields on many habitat types, including those of Fire Group Eight (Arno and Davis 1980; Barrett 1982).

Fire regimes interact with insects and diseases to shape Group Eight forests. Low- and mixed-severity fires increase structural complexity within stands and heterogeneity across the landscape. Low-severity fires favor dominance by western larch and, to a lesser extent, Douglas-fir. In the THPL/CLUN and THPL/ASCA habitat types, ponderosa pine may also be favored. Severe fires favor regeneration by seral species, including western white pine and western larch, which are relatively resistant to root disease and Indian paint fungus. Western white pine was dominant in many stands prior to the advent of western white pine blister rust, but planting of rust-resistant stock is now needed to obtain substantial western white pine regeneration (Byler and others 1994). As the forest matures, pines are thinned by bark beetles; diseased pines are especially susceptible (Kulhavy and others 1984). Root disease proliferates in the shade-tolerant species favored by fire exclusion (Minore 1979) and can reach levels at which usually resistant species are threatened (Byler and others 1990). Root disease accelerates succession from Douglas-fir and grand fir to climax species (Byler and others 1994). Increasing disease mortality may increase woody fuels and potential fire severity. Where severe root disease centers cause stands to stagnate in the stand initiation phase, heavy fuel loadings are unlikely.

Forest Succession

The path that succession is likely to follow in the rich, productive habitat types of Fire Group Eight depends on the site itself, the species present before the fire, the size and intensity of the burn, and postburn conditions. Nearly identical fire "situations" can produce very different postfire plant communities (Shiplett and Neuenschwander 1994). Early seral stands are very rich in shrub species. Tree regeneration may be rapid or may be delayed by competition from herbs and shrubs (Boyd 1969). Forest succession has been described for Fire Group Eight communities by Shiplett and Neuenschwander (1994) and for stands in the western hemlock series by Zack (1994) and Zack and Morgan (1994a). Our description of succession is based on these studies, historic reports of seral communities, autecological properties of species, and descriptions of species composition in mature Group Eight stands (Cooper and others 1991).

Profuse, diverse regeneration of herbs and shrubs after fire is typical of Group Eight stands. In 1/10 acre plots used to describe succession in the western hemlock series (Zack 1994), 41 shrub and 180 herb species were found; the average number of shrub species per plot was 17. Zack (1994) classified herb and shrub species according to the successional stage they dominate (table 38). A list of species likely to increase after severe fire (table 33) contains many of the same species. Additional important seral shrub species include *Amelanchier alnifolia*, *Holodiscus discolor*, *Physocarpus malvaceus*, and *Sambucus racemosa* (Drew 1967; Habeck 1985; Wittinger and others 1977; Zack 1994). Additional herbaceous species reported as dominants in early seral communities include *Iliamna rivularis*, *Erigeron* species, *Potentilla* species, and *Mitella stauropetala* (Drew 1967; Humphrey and Weaver 1915). Most understory species become established early in succession.

We use three pathways to describe forest succession in Fire Group Eight. Pathway 8.1 describes succession in stands where both seral and climax tree species become established after stand-replacing fire. This pathway is common in stands with fire return intervals averaging 120 years or more (Shiplett and Neuenschwander 1994), on sites with moderate moisture and temperature regimes. Pathway 8.2 describes succession where moist conditions, long fire return intervals, small burn area, or vagaries of seed supply and fire effects enable shade-tolerant species to dominate immediately after disturbance and persist throughout stand development. On sites with relatively short fire return intervals and frosty conditions (at least after overstory removal), lodgepole pine

Table 38—Dominant herb and shrub indicator species for successional stages in the western hemlock series (Zack 1994). Early successional species are those that require open space to establish or expand, and decline rapidly when overtopped. Midsuccessional species do not need open sites to establish or spread, and often respond to minor disturbance. They usually decline, however, in the absence of any disturbance.

	Successional stage	
	Early	**Middle**
Shrubs	*Ceanothus sanguineus*	*Alnus sinuata*
	Ceanothus velutinus	*Gaultheria ovatifolia*
	Ribes lacustre	*Mahonia repens*
	Ribes viscosissimum	*Rubus parviflorus*
		Salix scouleriana
		Spiraea betulifolia
		Symphoricarpos albus
		Vaccinium myrtillus
		Vaccinium scoparium
Herbs	Invader species[a]	*Arnica cordifolia*
	Carex concinnoides	*Arnica latifolia*
	Carex rossii	*Calamagrostis rubescens*
	Epilobium angustifolium	*Fragaria vesca*
		Fragaria virginiana
		Polemonium pulcherrimum
		Pteridium aquilinum

[a]Includes *Agoseris, Agrostis, Anaphalis, Centaurea, Chrysanthemum, Cinna, Cirsium, Conyza, Dactylis, Deschampsia, Elymus, Epilobium, Festuca, Gnaphalium, Hypericum, Koeleria, Lactuca, Plantago, Poa, Rumex, Solidago, Sonchus, Tanacetum, Taraxacum, Tragopogon,* and *Trifolium* species as well as *Bromus inermis* and *Phleum pratense.*

occasionally dominates early succession. We describe this pattern in Pathway 8.3. Where Group Eight stands intergrade with subalpine stands, the mixture of seral species is rich, but includes fewer western white pine and grand fir than at lower elevations. Habitat types where this may occur include TSHE/ASCA-MEFE, TSHE/CLUN-XETE, THPL/CLUN-MEFE, and THPL/CLUN-XETE. Succession is similar to that described in Pathway 5.2, with the addition of grand fir, cedar, and hemlock to the list of important species in mature stands, and decreased importance of subalpine fir.

The successional pathways described here are qualitative guides. Since stand development varies with seed source, presence and vigor of pathogens, and disturbance history, actual succession on a given site may follow a path intermediate between or diverging from those described here.

Pathway 8.1. Succession Dominated by a Mixture of Seral and Climax Species—After stand-replacing fire, forbs resprout and invade quickly, along with mosses and liverworts (Habeck 1970; Leiberg 1899a) (fig. 34 A). (Subsequent references in this section are to figure 34.) Grass dominance is unusual and hinders tree regeneration (Larsen 1925). Shrubs become dominant in 3 to 7 years and may dominate for as long as 30 years (Drew 1967; Wittinger and others 1977; Zack and Morgan 1994a). Shrub growth and longevity tend to be greater on south- than north-facing slopes, probably because canopy establishment takes longer on south aspects.

Conifers establish early in succession and emerge from the shrub canopy 15 to 30 years after fire (B) (Shiplett and Neuenschwander 1994; Zack and Morgan 1994a). Western white pine and western larch are the most widespread seral species, with western white pine more prevalent in the western redcedar series than in the western hemlock series (Cooper and others 1991). Western white pine has declined severely due to blister rust, however. Its role in succession is now filled largely by Douglas-fir and grand fir (Ferguson 1994; Zack 1994), which are susceptible to root disease; their decline accelerates succession to climax species (Byler and others 1994). This pattern of succession has little historic precedent in northern Idaho, so prediction of stand development is very difficult (McDonald 1995).

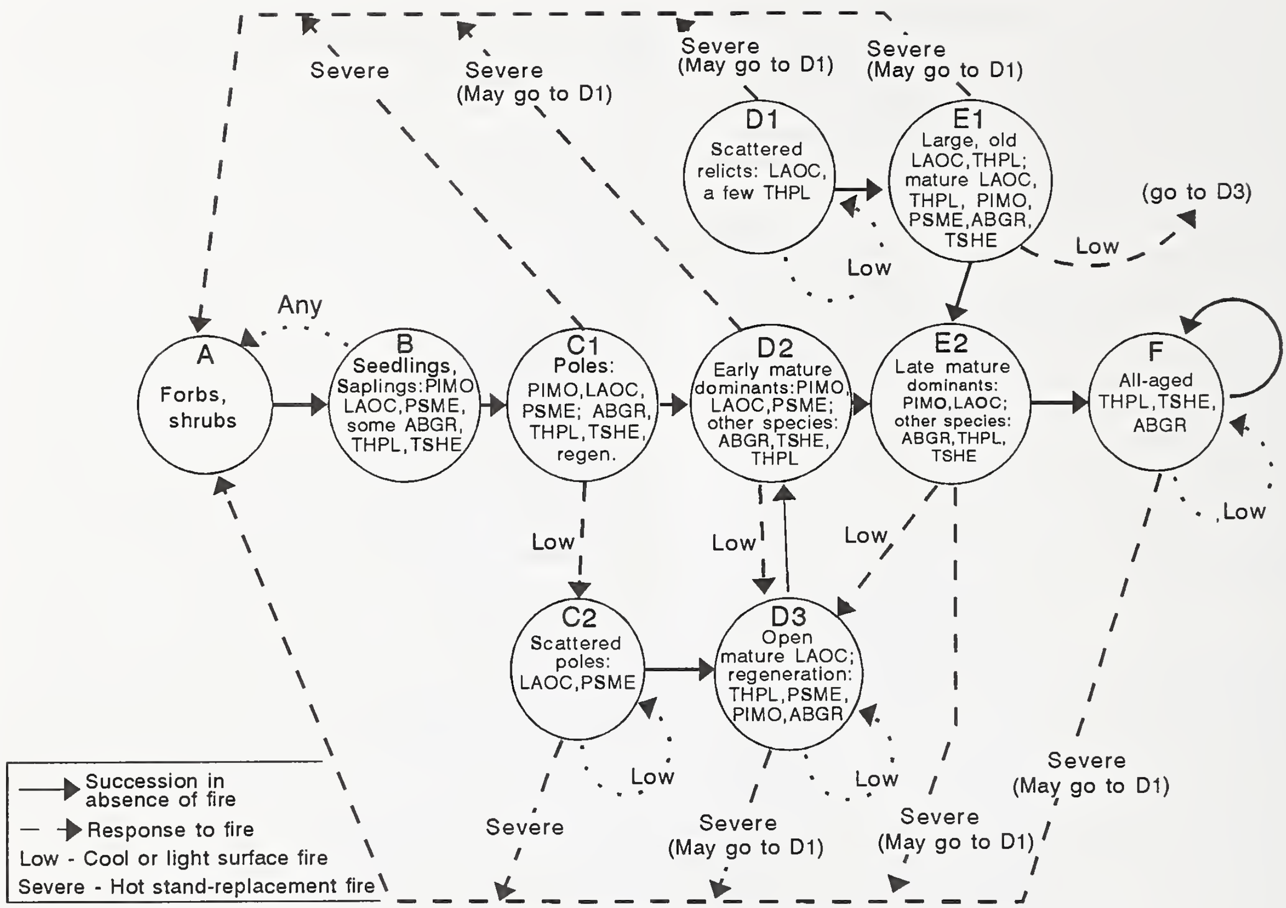

Figure 34—Pathway 8.1. Hypothetical fire-related succession for Fire Group Eight stands where succession is dominated by a mixture of seral and climax species. Succession is shown here for stands in the western hemlock series.

Western white pine and western larch both regenerate from wind-dispersed seed. Some viable western white pine seed may also be left in the crowns of burned trees (Haig and others 1941). Western larch seed may be available from relict trees. Western larch can overtop western white pine when the two species establish together (Shiplett and Neuenschwander 1994), since larch may initially grow 50 percent faster in height than seedlings of its competitors (Haig and others 1941; Larsen 1925). Douglas-fir and grand fir also establish after fire, but they usually do not outgrow shrubs in early succession (Zack 1994), and they are readily overtopped by western white pine and western larch (Haig and others 1941; Huberman 1935). Western hemlock and western redcedar may also establish early in succession; in Pathway 8.1, however, these species are overtopped for a century or more by seral trees (Marshall 1928; Zack and Morgan 1994a). Engelmann spruce and subalpine fir are important seral species only at relatively high elevations, and are often associated with *Menziesia ferruginea* and *Xerophyllum tenax* (Cooper and others 1991). Ponderosa pine is common in Pathway 8.1 only in the THPL/CLUN and THPL/ASCA habitat types. It is widespread in cedar-dominated river bottom sites of the Selway-Bitterroot Wilderness (Habeck 1970). Lodgepole pine is a minor species in this pathway.

Three hardwood species—paper birch, quaking aspen, and black cottonwood—can form the first tree-dominated successional stage on Group Eight sites, but they do so only to a limited extent in the Sandpoint and Bonners Ferry Districts, Kaniksu National Forest (Zack 1994). They are short-lived and are replaced by shade-tolerant conifers within a few decades. Stand 8E (fig. 32) illustrates such a stand; paper birch is declining, and the only other seral species is western larch. Understory trees are all western hemlock.

Fires occurring early in succession reduce the importance of western white pine. Low-severity fire during the pole stage (C1) may leave scattered western larch and a few Douglas-fir (C2). Where ponderosa pine is present, it will likely survive. Unlike stands on

less productive sites, Group Eight stands can burn severely early in succession because fuels are plentiful and continuous, and they dry rapidly after canopy removal (Barrett 1982; Haig and others 1941). Repeated severe burns prolong the shrub stage for a century or more (see "Persistent Seral Shrubfields"), during which isolated Douglas-fir, grand fir, cedar, and hemlock may regenerate (Antos 1977). As soil wood and organic matter are depleted by repeated burns, or if the soil is otherwise degraded, the likelihood of successful tree regeneration decreases (Barrett 1982; Harvey 1982).

As stands in Pathway 8.1 mature (D2), species dominance depends on interactions among tree species, insects, diseases, and fire. Mortality from root disease and Douglas-fir bark beetle reduces Douglas-fir before maturity (Haig and others 1941; Zack 1994). Low-severity fire favors western larch (D3). Without low-severity fire, western larch is vulnerable to pruning of lower branches by shade-tolerant understory trees and declines 100 to 140 years after establishment (Zack 1994). Western white pine is less resistant to fire but more tolerant of shade pruning than western larch. Where western white pine is not eliminated by low-severity fire or blister rust, it may continue to expand in dominance for 100 to 150 years after establishment and may continue to dominate in late seral stands (E2).

A few clusters of relict trees, sheltered by topographic features from the most severe fire behavior, may survive stand-replacing fire (D1). Western larch is the most common relict species in Fire Group Eight (Larsen 1929; Shiplett and Neuenschwander 1994), especially if large or growing vigorously. If seed from relict western larch is plentiful and conditions favor establishment, western larch dominates regeneration (E1). Many western larch 8 inches d.b.h. and larger survived a severe burn in Group Seven and Eight stands in the Idaho portion of the Bitterroot National Forest; 25 years later, the stands were dominated by western larch and grand fir (Humphrey and Weaver 1915).

The canopy of mature stands in Group Eight (E2) may be extremely dense, excluding most understory species (Cooper and others 1991). Western white pine can dominate for 200 to 350 years, or until mature trees decline because of mountain pine beetle (Huberman 1935). Blister rust infection increases susceptibility (Kulhavy and others 1984). Western larch is also long lived and is relatively resistant to insects and disease. Patchy, low-severity fires thin the understory. Some mature trees of all species may survive low-severity fire, but western larch is favored (D3).

If severe fire is excluded for many centuries, western white pine and western larch die out, leaving a stand dominated by shade-tolerant species (F). Succession to dominance by shade-tolerant species is often a very slow process unless accelerated by disease or partial cutting of seral species. Shiplett and Neuenschwander (1994) suggested that it takes place between 150 and 300 years after stand establishment. A 500 year old TSHE/MEFE stand in the Kaniksu National Forest was dominated by western hemlock, but Douglas-fir, western larch, and western white pine were still present, representing 58 feet^2 of basal area per acre (Moeur 1992).

Even after shade-intolerant species have declined, old-growth stands continue to develop structurally (Moeur 1992). A closed canopy and depauperate understory characterize early stages. As time passes, mortality from numerous sources, including disease, insects, wind, lightning, and low-severity fire, creates gaps in the canopy. Low-severity fires may kill trees directly or scar them, providing entry points for pathogens that eventually cause mortality. Finally, old-growth stands develop an open canopy composed of large, evenly spaced trees, with regeneration underneath. The most vigorous understory trees are those that germinate in canopy gaps, rather than advance regeneration. Very low-severity fire alters stand structure but has little effect on tree species composition. More severe fires kill all trees and return the site to herbs and shrubs (A), although relict western redcedars could remain.

Pathway 8.2. Succession Dominated by Shade-Tolerant Species—Shade-tolerant species often dominate throughout succession in moist, sheltered Group Eight stands and on north-facing slopes. This pathway also occurs on moderate sites after small or patchy burns (Larsen 1929; Marshall 1928), when seed from seral species is sparse, and when fire removes only part of the canopy and duff (Haig and others 1941). Cedar and hemlock can establish in nearly pure stands after fire. Cedar and grand fir are major seral species in the TSHE/ASCA-ARNU and TSHE/CLUN-ARNU habitat types (Cooper and others 1991). Douglas-fir, Engelmann spruce, and subalpine fir also occur in this pathway, but seldom dominate.

Although several studies describe seral and mature stands in this pathway, the processes of stand development and succession have not been described in detail. Dominant tree species have low or medium resistance to fire (table 5). Even low-severity fire, therefore, kills all trees in young stands and all but the largest trees in old forests. Western redcedar may be favored because of its ability to recover after fire if even a small amount of cambium survives. Although grand fir is somewhat shade tolerant, it is gradually replaced by climax species if disturbances do not create opportunities for regeneration. Stand 8C (fig. 32) represents such a stand; large cedar and grand fir dominate the overstory, but regeneration is almost exclusively cedar.

Pathway 8.3. Early Succession Dominated by Lodgepole Pine—Lodgepole pine dominates some areas in Fire Group Eight to the near exclusion of other tree species. Leiberg (1899a) found lodgepole pine dominating on lower flats and stream valley terraces in what is now the Priest Lake District, Kaniksu National Forest. A photograph in his report shows dense fire-killed poles near the outlet of Priest Lake, and a map indicates that lodgepole pine dominated the area just south of Priest Lake (Jack Pine Flats). Haig and others (1941) referred to dense lodgepole pine stands approximately 90 years old in the same area, and lodgepole pine still dominates on Jack Pine Flats. Habitat types include THPL/CLUN and TSHE/CLUN, with relatively high representation of subalpine fir (Coles 1992). According to Daubenmire and Pfister (1975), lodgepole pine can have a dominant seral role in the THPL/ASCA and THPL/CLUN habitat types. Cooper and others (1991) mentioned the potential for lodgepole pine to dominate "locally" in the TSHE/ASCA habitat type, as well as in Group Eight habitat types with substantial *Menziesia ferruginea* cover.

Pathway 8.3 occurs on benches and flats where canopy removal enhances pooling of cold air. It also occurs on sites with thin, dry, or rocky soils (Shiplett and Neuenschwander 1994), and on sites with seasonally high water tables. Western larch and other species may occur with lodgepole pine in this pathway but do not dominate. Frosty conditions enhance subalpine fir in the species mixture and inhibit establishment of Douglas-fir, grand fir, and climax species; high water tables enhance Engelmann spruce.

Succession has not been thoroughly described for Pathway 8.3. Because of lodgepole pine's ability to produce abundant seed when very young, Shiplett and Neuenschwander (1994) suggested that a reburn 20 or 30 years after stand-replacing fire favors lodgepole pine. A maturing lodgepole pine stand may gradually lower the stresses caused by temperature and water table fluctuations, making the site more favorable for regeneration of other species. Lodgepole pine peaks in vigor at about 50 years in Group Eight, and is seldom important after 100 years (Haig and others 1941). As lodgepole pine declines due to senescence and mountain pine beetle infestation, other species are released or regenerate. Haig and others (1941) reported western white pine, western larch, Douglas-fir, grand fir, and Engelmann spruce increasing on areas burned around 1850 and initially dominated by lodgepole pine. Lodgepole pine mortality produces heavy fuels, increasing the potential for severe fire, which perpetuates lodgepole pine dominance (Shiplett and Neuenschwander 1994).

Fire Management Considerations

Because presettlement intervals between severe fires were generally long in Fire Group Eight, the effects of fire exclusion are subtle. In the North Fork Clearwater Drainage, where the presettlement fire regime consisted mainly of stand-replacing fire (with nonlethal fire behavior along burn margins), measurable changes have not yet been effected by fire exclusion (Barrett 1993). Without disturbance, however, early successional communities generally become less common and landscape level biodiversity is reduced (Zack 1994). Since 1979, when prescribed natural fire was first considered a management option in most of the Selway-Bitterroot Wilderness, the average area burned annually by severe fire in the western redcedar fire regime type has been less than the average area burned by severe fire in presettlement times (Brown and others 1994). Severe fire can reduce site productivity, but continued fire exclusion is not without an ecological cost; it slows the recycling of carbon and nitrogen and favors tree species vulnerable to root disease (Harvey and others 1994).

Exclusion of low and mixed severity fire from Group Eight stands also has subtle ecological effects. Dense regeneration that develops in the absence of low-severity fire is linked to a decrease in vigor and crown volume of western larch and thus reduces fire resistance (Zack 1992). Over much of the landscape in the Selway District, Nez Perce National Forest, where presettlement fires in Group Eight stands were mostly of mixed severity, the time elapsed since the last fire is currently "at the outside of the range of natural variability" (Green 1994). More disturbance, but low- rather than high-intensity, is needed to restore western larch and ponderosa pine, both historically important species in this area. Loss of mixed-severity fire may lead to a coarser-grained landscape pattern and reduced ecological diversity (Brown and others 1994). Increasing homogeneity across landscapes can increase the potential for more extensive or more severe fire in the future. Management-ignited fire may be able to mimic some effects of presettlement fire in Group Eight stands, and mechanical reduction of surface and ladder fuels may expand future opportunities for the use of prescribed fire.

The decline of western white pine due to blister rust, combined with the decline of seral species caused by selective harvesting and fire exclusion (Byler and others 1990), have reduced management options in Fire Group Eight dramatically. Douglas-fir and grand fir have become major rather than minor components of early seral forests. Douglas-fir and grand fir regeneration may fail or stagnate, however, because of

susceptibility to root disease (Zack and Morgan 1994a); grand fir regeneration is also highly susceptible to Indian paint fungus (Ferguson and Carlson 1991). In severe root disease centers, disease levels and competition from shrubs impede forest development. Increased incidence of fire would produce conditions favorable to establishment of western white pine or western larch, but most natural western white pine regeneration fails because rust resistance is extremely limited in natural seed source. Restoration of western white pine in northern Idaho may require regeneration harvests at about 200 year intervals (McDonald 1995), and planting of rust-resistant western white pine in mixtures with other seral species (Byler and others 1994).

Management-ignited fire is used in Group Eight stands to enhance wildlife habitat, reduce fuel loadings, and favor seral tree species. Stands in this fire group are diverse, however. Where Group Eight stands occur in valley bottoms, on benches, and in ravines, minimizing disturbance may be crucial to soil and watershed protection; for management considerations, see Fire Group Nine. Management of stands in the Grand Fir Mosaic Ecosystem, which may contain THPL/ASCA-ASCA stands, is discussed in Fire Group Seven. Management of lodgepole pine stands is discussed in "Seral Lodgepole Pine in Northern Idaho."

Habitat for elk and deer on Group Eight sites is generally enhanced by fire. Shrub species favored by wildfire or broadcast burning are listed in tables 33 and 38. Fire severity affects the rate of shrub development on clearcut, broadcast-burned sites. Morgan and Neuenschwander (1988a, 1988b) found that shrubs developing from sprouts on broadcast burns in the THPL/CLUN habitat type, Clearwater National Forest, had greater cover on mildly burned sites (when little mineral soil was exposed and little woody fuel less than 3 inches in diameter was consumed) than on severely burned sites. In contrast, shrubs developing from seed had greater cover on severely burned sites.

Moose use double-canopied forests with a dense middle layer of *Taxus brevifolia* for winter range. See Fire Group Seven for discussion of fire effects in *Taxus* communities.

Abundant, high-quality timber, especially in the Group Eight habitat types, drove the settlement of northern Idaho by European Americans in the early 1900's, and timber production remains an important objective in these forests. Species composition and structural aspects of fire-shaped forests are used as patterns for designing timber harvests that sustain forest productivity. Byler and others (1994) noted that an effort to increase the proportion of root disease-tolerant species in stands historically dominated by western white pine would require regeneration cutting, especially in areas occupied by the 1910 burns. At the same time, large western white pines and western larches would need to be conserved, especially in areas with old-growth characteristics. On upland sites in the North Fork Clearwater River drainage, most presettlement burns were severe. Barrett (1993) suggested shelterwood and seedtree cuts to mimic stand replacement fires. To protect soils, a mosaic of even-age stands would be preferable to large, even-age stands. On north-facing slopes in the Cook Mountain area, even-age management with broadcast burning may be useful for regenerating western larch, the most successful seral species (Barrett 1982). Complete overstory removal, however, can create too harsh an environment for tree regeneration (Larsen 1922; Stickney 1982). A clearcut studied by Larsen (1922) had maximum daily temperatures averaging 7 °F higher than an uncut site, minimum temperatures 7 degrees colder, and twice as much water loss to evaporation. Western white pine requires 50 percent or more of full sunlight for germination, but seedlings survive in full sunlight only if moisture is plentiful (Haig and others 1941).

In the Selway District, Nez Perce National Forest, mixed-severity fire shaped most Group Eight stands in presettlement times. Harvesting with small to medium openings of mixed to high mortality could be used to enhance seral species on slopes; on ridges, seral species would be favored by small to moderate openings with low to mixed mortality (Green 1994). Shelter from residual overstory trees enhances regeneration on south-facing slopes (Ferguson and others 1986). In mature stands of Fire Group Eight, selective cutting could be useful for opening the canopy and encouraging regeneration (Moeur 1992, 1994). Trees of any species may suffer wind damage after partial cutting (Haig and others 1941; Simmerman and others 1991). Underburning is complex and hazardous on north-facing slopes. Dense stands with ladder fuels may burn well only when fuels are dry enough to sustain a stand-replacing fire.

Fire has been used after timber harvest in Group Eight stands to reduce fuels and enhance regeneration. After shelterwood cutting in the western redcedar series, Priest River Experimental Forest, western larch and ponderosa pine germinated three to 12 times more successfully on burned than unburned plots (Simmerman and others 1991). Burning on THPL/CLUN-CLUN sites in northern Idaho decreased duff porosity and brought seed into close contact with the seedbed. Burning enhanced natural regeneration of Douglas-fir, western larch, western white pine, and ponderosa pine even when considerable duff remained (fig. 35) (Boyce 1985; Boyce and Neuenschwander 1989). Burning reduced seed-destroying insects for 2 years after fire on stands in the western redcedar series in the Clearwater National Forest (Fellin and Kennedy 1972). On THPL/CLUN-CLUN sites, Palouse

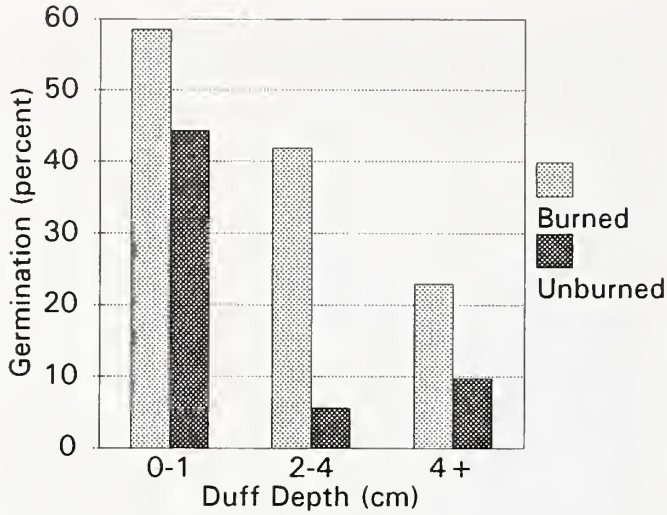

Figure 35—Average percent germination of viable Douglas-fir seed on different depths of burned and unburned seedbeds in the THPL/CLUN-CLUN habitat type (Boyce and Neuenschwander 1989).

Ranger District, Clearwater National Forest, leader growth on planted Douglas-fir was 7 to 16 percent greater on burned than scarified sites (Eramian and Neuenschwander 1989).

Tree regeneration is usually rapid in Group Eight, but site preparation and planting are needed if a high proportion of western white pine or western larch is desired in regeneration (Boyd 1969; Zack and Morgan 1994a). To regenerate with western white pine, Byler and others (1990) recommended planting or seeding a mixture of species containing large proportions of western larch and rust-resistant western white pine (and ponderosa pine in the western redcedar series). Cutting methods and site preparation should be planned to minimize the resurgence of *Ribes* species after treatment. On west aspects, naturally low *Ribes* occurrence may favor western white pine regeneration (Ferguson 1994).

Damage to the volcanic ash layer present in soils on most Group Eight sites decreases productivity substantially (Ferguson 1994). Management activities on these sites must preserve the ash cap and protect soil porosity and organic matter. Page-Dumroese (1993) described harvesting practices that minimize soil compaction and loss of organic matter. On sites in the western redcedar series, dozer scarification increased the bulk density of upper soil layers 10 to 20 percent over that found on undisturbed sites; broadcast burning increased bulk density 3 to 12 percent (Eramian and Neuenschwander 1989). Effects of multiple stand entries on compaction should be assessed in plans for uneven-age management. Organic matter originates in soil wood, large woody debris, duff, and other plant material. Soil wood is an excellent seedbed for tree regeneration because it retains moisture well, hosts more micorrhizae than humus, and reduces nonconifer competition and decay fungi (Harvey 1982). Natural mortality and logging debris are sources of future soil wood (Page-Dumroese and others 1994). Graham and others (1994) recommended leaving 15.5 to 33 tons per acre of residual debris on sites in the TSHE/CLUN habitat type. Slash can be lopped and scattered to accelerate its decay and minimize its potential contribution to wildfire spread. Where Group Eight stands occur on wet sites between roads and streams, plans for roadside fuel reduction should consider protection of soils, the need for retaining considerable large woody material, and protection of snags as nesting and roosting sites for cavity-nesting birds.

Fire Group Nine: Very Moist Western Redcedar Habitat Types

Thuja plicata/Adiantum pedatum h.t. (THPL/ADPE), western redcedar/maidenhair fern

Thuja plicata/Athyrium filix-femina h.t. - *Adiantum pedatum* phase (THPL/ATFI-ADPE), western redcedar/lady-fern - maidenhair fern phase

Thuja plicata/Athyrium filix-femina h.t. - *Athyrium filix-femina* phase (THPL/ATFI-ATFI), western redcedar/lady-fern - lady-fern phase

Thuja plicata/Oplopanax horridum h.t. (THPL/OPHO), western redcedar/devil's club

Vegetation

The habitat types of Fire Group Nine occupy very moist forests in northern Idaho. They comprise the "giant cedar groves" with high canopies and moist understories. Most are in valley bottoms or on lower slopes with high water tables. Very large western redcedar, western hemlock, and grand fir dominate old growth and often younger stands as well (fig. 36, table 39). Seral species vary, depending on temperature regime and drainage conditions.

In Group Nine stands, *Acer glabrum*, *Alnus sinuata*, *Oplopanax horridum*, *Salix scouleriana*, and *Taxus brevifolia* can grow very large. Ferns, especially *Adiantum pedatum*, *Athyrium filix-femina*, and *Gymnocarpium dryopteris*, are conspicuous in the understory. Additional important herbs include the following:

Figure 36—Vegetation and fuels in Group Nine stands. All stands are dominated by a mixture of western redcedar and grand fir. (See table 39.) A. Stand 9A, in St. Maries District, St. Joe National Forest, has an understory containing grand fir, cedar, Pacific yew, and subalpine fir. B. Stand 9B. Cedar, pacific yew, and grand fir dominate the understory, but Douglas-fir and paper birch also occur. C. Stand 9C. Ferns and *Oplopanax horridum* are profuse; tree regeneration is sparse. D. Stand 9D. Overstory contains a few western larch and Douglas-fir. Sparse tree regeneration consists of cedar and grand fir. Stands 9B-9D are in the North Fork District, Clearwater National Forest. Photos by Jim Mital.

Actaea rubra	*Dryopteris filix-mas*
Adenocaulon bicolor	*Mertensia paniculata*
Asarum caudatum	*Senecio triangularis*
Botrychium virginianum	*Stellaria crispa*
Circaea alpina	*Streptopus amplexifolia*
Clintonia uniflora	*Tiarella trifoliata*
Coptis occidentalis	*Trautvetteria caroliniensis*
Disporum hookeri	*Trillium ovatum*
Dryopteris austriaca	*Viola glabella*

Fuels

Group Nine sites are famous for their large trees and lush undergrowth (fig. 36). Duff is usually continuous and deep. Woody fuels may be light or heavy, depending on site history, stand structure, and moisture conditions. High rates of decomposition, especially in old-growth stands, often contribute to relatively low woody fuel loadings (Shiplett and Neuenschwander 1994). Total downed woody fuel loadings ranging from 0.7 to 38.6 tons per acre have been reported for Group Nine stands in northern Idaho (table 39). In the Kootenai National Forest, western Montana, Fischer (1981a) found 57.6 tons per acre in an old-growth (400 years old or older) THPL/OPHO stand.

During moist and moderate summers, the likelihood of extensive fires in Fire Group Nine stands is low; very moist cedar groves may even serve as firebreaks (Parker and Johnson 1994). Deep, moist undergrowth accounts for low flammability of surface fuels and duff. Ferns cover the forest floor in Stands 9A and 9D (fig. 36). *Oplopanax horridum* forms an almost continuous,

Table 39—Stand characteristics and fuel loadings for Group Nine stands shown in figure 36. Fuel loadings are in tons per acre. (Data were provided by Jim Mital and are on file at Intermountain Fire Sciences Laboratory, Missoula, MT.)

Stand No.	Habitat type-phase	Age	Tree spp.	Canopy cover	Litter, duff depth	Dead and down load by size class (inches) 0-¼	¼-1	1-3	3+ sound	3+ rotten	Total dead and down load
		Years		*Percent*	*Inches*	*Tons per acre*					
9A[a]	THPL/ATFI-ATFI	300	THPL	70	4.9	0.0	0.3	0.4	0.0	0.0	0.7
			ABGR	10							
9B	THPL/ADPE	150	THPL	40	1.3	0.1	0.6	1.9	0.0	2.4	5.0
			ABGR	30							
			TABR	20							
9C	THPL/OPHO	175	THPL	99	2.2	0.1	0.6	0.8	0.0	16.5	18.0
			ABGR	99							
9D	THPL/ADPE	200	ABGR	99	1.5	0.1	1.6	2.2	2.7	32.0	38.6
			THPL	70							

[a]Refers to stand number in text.

moist shrub layer in Stand 9C. Stand 9B also has widespread ferns, but tree regeneration increases the susceptibility of the overstory to torching and crowning under very dry conditions. During drought years, Group Nine stands occasionally support low- and mixed-severity fire; severe fires may enter Group Nine stands from adjacent sites. During drought, the likelihood of severe fire is especially great in narrow stringers of Group Nine habitat types.

Role of Fire

Most forests in Group Nine persist for many centuries without severe fire (Cooper and others 1991). Parker and Johnson (1994) estimated that some of the largest cedars in northern Idaho are over 3,000 years old. Valley-bottom stands probably burned less frequently than upland stands (Habeck 1973). Widespread occurrence of shade-intolerant species in Group Nine (Cooper and others 1991), however, indicates a history that included occasional severe fire. In the Deception Creek Experimental Forest, for example, a TSHE/ATFI stand was dominated by western white pine until attacked by blister rust in the 1940's, and mountain pine beetle in the 1960's and 1970's (Moeur 1992); it is now dominated by medium sized western hemlock. Giant cedar groves burned by stand-replacing fire in this century include those in the Pack River, burned in 1967, and in the upper reaches of the North Fork St. Joe River, burned in 1910. These fires burned into Group Nine stands with momentum from severe, fast-moving crown fire in adjacent stands. Large, tall cedar snags were still standing more than 80 years after the fire on the St. Joe River (fig. 37). Vegetation was dominated by *Salix* species and other tall shrubs. Tree regeneration consisted of black cottonwood and a few Engelmann spruce.

Only one study from northern Idaho (Barrett 1993) reports an average interval between stand-replacing fires that is based only on habitat types in Fire Group Nine, and that is reported as a minimum of 292 years (table 40). Agee (1993) used "episodic" rather than "cyclic" to describe fire return intervals in western hemlock forests of the Pacific Northwest. He suggested that average fire return intervals are not particularly meaningful in forests where fire history rarely extends far enough into the past to record several intervals, and climatic change during that history would have altered the fire regime.

A history of low- and mixed-severity fire has been reported for Group Nine stands from several areas in northern Idaho (table 40). At least some of these fires originated with lightning strikes within the stands.

Figure 37—Group Nine site on the North Fork St. Joe River, St. Joe National Forest, more than 80 years after stand-replacing fire.

Table 40—Presettlement fire regimes for Fire Group Nine habitat types in northern Idaho. Mean fire interval and standard deviation (s.d.) are computed from stand mean fire intervals for the study area. Fire interval range lists minimum and maximum individual intervals from the study area. Locations of studies are shown in figure 1.

Location, habitat types, cover	Fire severity	Years: Fire interval range	Years: Mean fire interval	Years: S.d.	Number of stands
Priest River Basin[a]: —THPL/ATFI,/OPHO	Mostly low severity; lethal fires rare		>200		
North Fork Clearwater R.[b]: —THPL/ADPE,/ATFI	Stand replacing	200+ to 430+	292+		6
	Nonlethal	24 to 200	126	67	5
Selway-Bitterroot[c]: —THPL/ASCA,/ATFI,/CLUN	Stand replacing		197		9

[a]Arno and Davis (1980).
[b]Barrett (1993). "+" indicates fire interval was incomplete at time of study but its inclusion did not shorten mean.
[c]Barrett and Arno (1991), Brown and others (1994, 1995). Includes stands in both Fire Group Eight and Fire Group Nine.

Approximately one in 50 old-growth cedars in the Selway-Bitterroot Wilderness has been struck by lightning (Habeck 1976); most scarred trees occur either singly or in clusters of three or four (Habeck 1973). Trees with one or two fire scars are common in Group Nine habitat types in the Selway District, Nez Perce National Forest (Green 1994). Severe fires entering Group Nine stands from adjacent, drier habitat types sometimes decrease in severity and become low- or mixed-severity fire. In the North Fork Clearwater River drainage, the 1910 fire scarred a few western redcedar adjacent to areas burned by extensive stand-replacing fire (Barrett 1993).

Forest Succession

Descriptions of successional pathways in Fire Group Nine are lacking in the literature, and descriptions of early seral stands are few. Stand development after fire depends on fire size and severity, as well as changes in drainage and microclimate. Since severe fires are accompanied by stand removal over a large geographic area, stand-replacing fire may be followed by a significant rise in the water table. *Salix scouleriana* often dominates such wet sites (see fig. 37), providing excellent summer habitat for moose. Beaver may thrive on these sites, prolonging the wet conditions (Zack 1992). Canopy removal also increases the likelihood of frosty conditions, favors shrub dominance, and retards establishment of the ferns and herbs characteristic of climax stands. Reforestation of Group Nine sites may require more than 100 years.

The tree species that establish on Group Nine burns vary with postburn conditions. Shade-tolerant species are favored in small openings, especially if duff is not removed. In larger openings, hardwoods and shade-intolerant conifers can overtop climax species and so dominate early seral stages. Black cottonwood is often important in such stands. On sites with good drainage, western white pine, western larch, and Douglas-fir all occur (Cooper and others 1991; Moeur 1992). Cold conditions favor Engelmann spruce and occasional lodgepole pine. Subalpine fir may become established on well drained, cold sites. Rotting logs are the best microsites for tree establishment; root crowns of fallen trees are also good seedbeds (Johnson and Parker 1994). "Nurse logs" may provide microsites elevated from seasonally saturated soils (Daubenmire and Daubenmire 1968).

Cover from the maturing forest moderates moisture and temperature conditions in Group Nine, enabling cedar, hemlock, and grand fir to establish in the understory. A closed canopy and depauperate understory characterize stands early in maturity (Moeur 1992). Daubenmire and Daubenmire (1968) attributed the lack of undergrowth to soil surface drought. Mortality from disease, wind, and low-severity fire creates gaps in the canopy where shade-tolerant species reproduce. In 200 year old TSHE/ATFI stands in the Deception Creek Experimental Forest, Moeur (1992) found western hemlock, grand fir, and a few Douglas-fir regenerating in canopy gaps. Western white pine was absent, even though it dominated the early-successional stand. As shade-intolerant species decline, cedar- or hemlock-dominated stands develop. Reproduction consists mainly of cedar, hemlock, and grand fir. Old-growth stands develop an open canopy composed of large, evenly spaced trees, with mostly cedar or hemlock regeneration beneath. The most vigorous understory trees originate in canopy gaps, not in shade (Moeur 1994).

Fire Management Considerations

Fire exclusion has not produced measurable effects on Group Nine stands (Barrett 1993; Green 1994). Subtle effects, however, have probably occurred. Without disturbance, the proportion of seral species in natural stands declines, and western redcedar and western hemlock are more likely to dominate. Single-tree removal would enable shade-tolerant species to regenerate, but larger openings would be needed to favor shade-intolerant species (Moeur 1992). The potential for severe fire on Group Nine sites is increased in areas where fire exclusion has increased the likelihood of stand-replacing fire on adjacent, drier sites. Managers may continue to try to exclude fire from old growth stands in Group Nine for this reason, and also because of their esthetic appeal and their value as habitat for large ungulates (Cooper and others 1991).

Because water tables are near the surface and soils are easily compacted and susceptible to severe erosion, management activities in Group Nine should constrain the use of heavy equipment (Cooper and others 1991). Effects of multiple stand entries on compaction should be assessed in plans for uneven-age management (Page-Dumroese and others 1994). Salvage and firewood cutting should be limited because regeneration requires ample soil wood and nurse logs. Where Group Nine stands occur near roads, plans for roadside fuel reduction should consider protection of soils, the need for retaining considerable large woody material, and protection of snags as nesting and roosting sites for cavity-nesting birds.

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Appendix A: Northern Idaho Forest Habitat Types and Phases (Cooper and Others 1991) and Fire Groups

Abbreviation	Scientific name	Common name	Fire group
TSHE	*Tsuga Heterophylla* Series		
TSHE/GYDR	*T. heterophylla/Gymnocarpium dryopteris* h.t.	Western hemlock/oak-fern	8
TSHE/ASCA	*T. heterophylla/Asarum caudatum* h.t.	Western hemlock/wild ginger	
-ARNU	-*Aralia nudicaulis* phase	-wild sarsaparilla	8
-MEFE	-*Menziesia ferruginea* phase	-menziesia	8
-ASCA	-*Asarum caudatum* phase	-wild ginger	8
TSHE/CLUN	*T. heterophylla/Clintonia uniflora* h.t.	Western hemlock/queencup beadlily	
-ARNU	-*Aralia nudicaulis* phase	-wild sarsaparilla	8
-MEFE	-*Menziesia ferruginea* phase	-menziesia	8
-XETE	-*Xerophyllum tenax* phase	-beargrass	8
-CLUN	-*Clintonia uniflora* phase	-queencup beadlily	8
TSHE/MEFE	*T. heterophylla/Menziesia ferruginea* h.t.	Western hemlock/menziesia	5
THPL	*Thuja Plicata* Series		
THPL/OPHO	*T. plicata/Oplopanax horridum* h.t.	Western redcedar/devil's club	9
THPL/ATFI	*T. plicata/Athyrium filix-femina* h.t.	Western redcedar/lady-fern	
-ADPE	-*Adiantum pedatum* phase	-maidenhair fern	9
-ATFI	-*Athyrium filix-femina* phase	-lady-fern	9
THPL/ADPE	*T. plicata/Adiantum pedatum* h.t.	Western redcedar/maidenhair fern	9
THPL/GYDR	*T. plicata/Gymnocarpium dryopteris* h.t.	Western redcedar/oak-fern	8
THPL/ASCA	*T. plicata/Asarum caudatum* h.t.	Western redcedar/wild ginger	
-MEFE	-*Menziesia ferruginea* phase	-menziesia	8
-TABR	-*Taxus brevifolia* phase	-Pacific yew	8
-ASCA	-*Asarum caudatum* phase	-wild ginger	8
THPL/CLUN	*T. plicata/Clintonia uniflora* h.t.	Western redcedar/queencup beadlily	
-MEFE	-*Menziesia ferruginea* phase	-menziesia	8
-TABR	-*Taxus brevifolia* phase	-Pacific yew	8
-XETE	-*Xerophyllum tenax* phase	-beargrass	8
-CLUN	-*Clintonia uniflora* phase	-queencup beadlily	8
TSME	*Tsuga Mertensiana* Series		
TSME/STAM	*T. mertensiana/Streptopus amplexifolius* h.t.	Mountain hemlock/twisted-stalk	
-LUHI	-*Luzula hitchcockii* phase	-smooth woodrush	5
-MEFE	-*Menziesia ferruginea* phase	-menziesia	5
TSME/CLUN	*T. mertensiana/Clintonia uniflora* h.t.	Mountain hemlock/queencup beadlily	
-MEFE	-*Menziesia ferruginea* phase	-menziesia	5
-XETE	-*Xerophyllum tenax* phase	-beargrass	5
TSME/MEFE	*T. mertensiana/Menziesia ferruginea* h.t.	Mountain hemlock/menziesia	
-LUHI	-*Luzula hitchcockii* phase	-smooth woodrush	5
-XETE	-*Xerophyllum tenax* phase	-beargrass	5
TSME/XETE	*T. mertensiana/Xerophyllum tenax* h.t.	Mountain hemlock/beargrass	
-LUHI	-*Luzula hitchcockii* phase	-smooth woodrush	4
-VASC	-*Vaccinium scoparium* phase	-grouse whortleberry	4
-VAGL	-*Vaccinium globulare* phase	-blue huckleberry	4
TSME/LUHI	*T. mertensiana/Luzula hitchcockii* h.t.	Mountain hemlock/smooth woodrush	6
ABLA	*Abies Lasiocarpa* Series		
ABLA/CACA	*A. lasiocarpa/Calamagrostis canadensis* h.t.	Subalpine fir/bluejoint	
-LEGL	-*Ledum glandulosum* phase	-Labrador-tea	5
-VACA	-*Vaccinium caespitosum* phase	-dwarf huckleberry	5
-LICA	-*Ligusticum canbyi* phase	-Canby's ligusticum	5
-CACA	-*Calamagrostis canadensis* phase	-bluejoint	5
ABLA/STAM	*A. lasiocarpa/Streptopus amplexifolius* h.t.	Subalpine fir/twisted-stalk	
-MEFE	-*Menziesia ferruginea* phase	-menziesia	5
-LICA	-*Ligusticum canbyi* phase	-Canby's ligusticum	5
ABLA/CLUN	*A. lasiocarpa/Clintonia uniflora* h.t.	Subalpine fir/queencup beadlily	
-MEFE	-*Menziesia ferruginea* phase	-menziesia	5
-XETE	-*Xerophyllum tenax* phase	-beargrass	5
-CLUN	-*Clintonia uniflora* phase	-queencup beadlily	5
ABLA/MEFE	*A. lasiocarpa/Menziesia ferruginea* h.t.	Subalpine fir/menziesia	
-LUHI	-*Luzula hitchcockii* phase	-smooth woodrush	5
-VASC	-*Vaccinium scoparium* phase	-grouse whortleberry	5
-COOC	-*Coptis occidentalis* phase	-western goldthread	5
-XETE	-*Xerophyllum tenax* phase	-beargrass	5

(con.)

Appendix A (Con.)

Abbreviation	Scientific name	Common name	Fire group
ABLA/VACA	*A. lasiocarpa/Vaccinium caespitosum* h.t.	Subalpine fir/dwarf huckleberry	3
ABLA/XETE	*A. lasiocarpa/Xerophyllum tenax* h.t.	Subalpine fir/beargrass	
-LUHI	-*Luzula hitchcockii* phase	-smooth woodrush	4
-VASC	-*Vaccinium scoparium* phase	-grouse whortleberry	4
-COOC	-*Coptis occidentalis* phase	-western goldthread	4
-VAGL	-*Vaccinium globulare* phase	-blue huckleberry	4
ABLA/VAGL	*A. lasiocarpa/Vaccinium globulare* h.t.	Subalpine fir/blue huckleberry	4
ABLA/CARU	*A. lasiocarpa/Calamagrostis rubescens* h.t.	Subalpine fir/pinegrass	4
ABLA/VASC	*A. lasiocarpa/Vaccinium scoparium* h.t.	Subalpine fir/grouse whortleberry	3
ABLA/LUHI	*A. lasiocarpa/Luzula hitchcockii* h.t.	Subalpine fir/smooth woodrush	6
LALY-ABLA	*Larix lyallii-Abies lasiocarpa* communities	Alpine larch-subalpine fir	6
PIAL-ABLA	*Pinus albicaulis-Abies lasiocarpa* communities	Whitebark pine-subalpine fir	6
ABGR	*Abies Grandis* Series		
ABGR/SETR	*A. grandis/Senecio triangularis* h.t.	Grand fir/arrowleaf groundsel	7
ABGR/ASCA	*A. grandis/Asarum caudatum* h.t.	Grand fir/wild ginger	
-MEFE	-*Menziesia ferruginea* phase	-menziesia	7
-TABR	-*Taxus brevifolia* phase	-Pacific yew	7
-ASCA	-*Asarum candatum* phase	-wild ginger	7
ABGR/CLUN	*A. grandis/Clintonia uniflora* h.t.	Grand fir/queencup beadlily	
-TABR	-*Taxus brevifolia* phase	-Pacific yew	7
-MEFE	-*Menziesia ferruginea* phase	-menziesia	7
-XETE	-*Xerophyllym tenax* phase	-beargrass	7
-PHMA	-*Physocarpus malvaceus* phase	-ninebark	7
-CLUN	-*Clintonia uniflora* phase	-queencup beadlily	7
ABGR/LIBO	*A. grandis/Linnaea borealis* h.t.	Grand fir/twinflower	
-XETE	-*Xerophyllum tenax* phase	-beargrass	7
-LIBO	-*Linnaea borealis* phase	-twinflower	7
ABGR/XETE	*A. grandis/Xerophyllum tenax* h.t.	Grand fir/beargrass	
-COOC	-*Coptis occidentalis* phase	-western goldthread	7
-VAGL	-*Vaccinium globulare* phase	-blue huckleberry	7
ABGR/VAGL	*A. grandis/Vaccinium globulare* h.t.	Grand fir/blue huckleberry	7
ABGR/PHMA	*A. grandis/Physocarpus malvaceus* h.t.	Grand fir/ninebark	
-COOC	-*Coptis occidentalis* phase	-western goldthread	2
-PHMA	-*Physocarpus malvaceus* phase	-ninebark	2
ABGR/SPBE	*A. grandis/Spiraea betulifolia* h.t.	Grand fir/white spiraea	2
PSME	*Pseudotsuga Menziesii* Series		
PSME/PHMA	*P. menziesii/Physocarpus malvaceus* h.t.	Douglas-fir/ninebark	
-SMST	-*Smilacina stellata* phase	-starry Solomon-seal	2
-PHMA	-*Physocarpus malvaceus* phase	-ninebark	2
PSME/VACA	*P. menziesii/Vaccinium caespitosum* h.t.	Douglas-fir/dwarf huckleberry	2
PSME/VAGL	*P. menziesii/Vaccinium globulare* h.t.	Douglas-fir/blue huckleberry	2
PSME/SYAL	*P. menziesii/Symphoricarpos albus* h.t.	Douglas-fir/common snowberry	1
PSME/SPBE	*P. menziesii/Spiraea betulifolia* h.t.	Douglas-fir/white spiraea	1
PSME/CARU	*P. menziesii/Calamagrostis rubescens* h.t.	Douglas-fir/pinegrass	
-ARUV	-*Arctostaphylos uva-ursi* phase	-kinnikinnick	2
-CARU	-*Calamagrosits rubescens* phase	-pinegrass	2
PSME/CAGE	*P. menziesii/Carex geyerii* h.t.	Douglas-fir/elk sedge	2
PSME/FEID	*P. menziesii/Festuca idahoensis* h.t.	Douglas-fir/Idaho fescue	1
PSME/AGSP	*P. menziesii/Agropyron spicatum* h.t.	Doulgas-fir/bluebunch wheatgrass	1
PICO	*Pinus Contorta* Series		
PICO/VACA	*P. contorta/Vaccinium caespitosum* c.t.	Lodgepole pine/dwarf huckleberry	3
PICO/XETE	*P. contorta/Xerophyllum tenax* c.t.	Lodgepole pine/beargrass	3
PICO/VASC	*P. contorta/Vaccinium scoparium* h.t.	Lodgepole pine/grouse whortleberry	3
PIPO	*Pinus Ponderosa* Series		
PIPO/PHMA	*P. ponderosa/Physocarpus malvaceus* h.t.	Ponderosa pine/ninebark	2
PIPO/SYAL	*P. ponderosa/Symphoricarpos albus* h.t.	Ponderosa pine/common snowberry	1
PIPO/FEID	*P. ponderosa/Festuca idahoensis* h.t.	Ponderosa pine/Idaho fescue	1
PIPO/AGSP	*P. ponderosa/Agropyron spicatum* h.t.	Ponderosa pine/bluebunch wheatgrass	1

Appendix B: Incidental and Rare Habitat Types and Plant Communities That are Known or Suspected to Occur in Northern Idaho (Cooper and Others 1991, Appendix I) and Their Fire Groups

Abbreviation	Scientific name	Fire group
TSHE/ADPE	*Tsuga heterophylla/Adiantum pedatum*	9
TSHE/CLUN-TABR	*Tsuga heterophylla/Clintonia uniflora-Taxus brevifolia* phase	8
TSHE/XETE	*Tsuga heterophylla/Xerophyllum tenax*	4
TSHE/ATFI	*Tsuga heterophylla/Athyrium filix-femina*	9
TSHE/OPHO	*Tsuga heterophylla/Oplopanax horridum*	9
THPL/LYAM	*Thuja plicata/Lysichitum americanum*	9
THPL/EQUI	*Thuja plicata/Equisetum* spp.	9
THPL/CLUN-PHMA	*Thuja plicata/Clintonia uniflora-Physocarpus malvaceus* phase	8
THPL/COOC	*Thuja plicata/Coptis occidentalis*	8
THPL/PHMA	*Thuja plicata/Physocarpus malvaceus*	8
THPL/DRSP	*Thuja plicata/Dryopteris* spp.	8
TSME/LUHI	*Tsuga mertensiana/Luzula hitchcockii*	6
ABLA/CABI	*Abies lasiocarpa/Caltha biflora*	5
ABLA/OPHO	*Abies lasiocarpa/Oplopanax horridum*	5
ABLA/CACA-CACA	*Abies lasiocarpa/Calamagrostis canadensis*-CACA phase	5
ABLA/COOC-COOC	*Abies lasiocarpa/Coptis occidentalis*-COOC phase	5
ABLA/RHAL	*Abies lasiocarpa/Rhododendron albiflorum*	5
ABLA/XETE-XETE	*Abies lasiocarpa/Xerophyllum tenax*-XETE phase	4
ABGR/ADPE	*Abies grandis/Adiantum pedatum*	7
ABGR/ACGL-PHMA	*Abies grandis/Acer glabrum-Physocarpus malvaceus* phase	2
ABGR/COOC	*Abies grandis/Coptis occidentalis*	7
PSME/FESC	*Pseudotsuga menziesii/Festuca scabrella*	1
PIPO/PHMA-CRDO	*Pinus ponderosa/Physocarpus malvaceus-Crataegus douglasii* phase	2
PIEN/EQUI	*Picea engelmannii/Equisetum* spp.	5
ALIN	*Alnus incana* communities	0
PTAQ	*Pteridium aquilinum* communities	0

Appendix C: Correspondence Among Fire Groups for Several Geographic Areas

A small number at the left side of a column indicates that the community type is a member of the fire group with that number, in the area represented by that column. Shaded, vertical boxes bracket community types typical of each fire group and are labeled with the fire group number. The vertical boxes may not contain all types in a fire group, however, and may include some types belonging to other groups.

Series, habitat or cover type (h.t., c.t.), or phase[a]	Montana[b] (MT)	Northern Idaho[c] (NID)	Central Idaho[d] (CID)	Eastern ID, western WY[e] (EIWW)	Utah[f] (UTAH)
					1 **UTAH-1:** Pinyon-juniper woodlands
					2 **UTAH-2:** Montane maple-oak woodlands
***Pinus flexilis* series:**	1 **MT-1:** Dry limber pine h.t.s		1 **CID-1:** Dry limber pine h.t.s	1 **EIWW-1:** Limber pine h.t.s	9 **UTAH-9:** Climax stands dominated by limber pine or W. bristlecone
***Pinus ponderosa* series:**					
/Stipa occidentalis			2 **CID-2:** Warm, dry h.t.s that support open forests of PP or DF[g]		
/Andropogon spp.	2 **MT-2:** Warm, dry PP h.t.s				
/Agropyron spicatum	2	1 **NID-1:** Warm, dry DF & PP h.t.s	2		
/Arctostaphylos patula					3 **UTAH-3:** PP h.t.s
/Artemisia nova					3
/Carex geyeri			2		3
/Cercocarpus ledifolius			2		3
/Festuca idahoensis	2	1	2		3
/Purshia tridentata			2		3
/Symphoricarpos oreophilus			2		3
/Symphoricarpos albus		1	3 **CID-3:** Warm, moist PP h.t.s & DF h.t.s usually dominated by PP		
-Symphoricarpos albus			2		3
-Berberis repens	3				

Series, h.t., c.t.	MT	NID	CID	EIWW	UTAH
/Quercus gambelii					3
/Muhlenbergia montana					3
/Symphoricarpos occidentalis	2				
/Arctostaphylos uva-ursi	2				
/Juniperus horizontalis	2				
/Juniperus scopulorum	2				
/Berberis repens	3 **MT-3:** Warm, moist PP h.t.s				
/Amelanchier alnifolia	3				
/Prunus virginiana	3				
/Physocarpus malvaceus		2	3		
***Pseudotsuga menziesii* series:**					
/Agropyron spicatum	4 **MT-4:** Warm, dry DF h.t.s	1	2		
/Festuca idahoensis	5	1	2	2	
/Festuca scabrella	4				
/Symphoricarpos albus		1			
-Agropyron spicatum	4				
-Symphoricarpos albus	6		4	3 **EIWW-3:** Moist DF h.t.s	
-Calamagrostis rubescens	6				
-Pinus ponderosa			3		
/Symphoricarpos occidentalis	4				
/Arctostaphylos uva-ursi	4				
/Spiraea betulifolia	4	1			
-Pinus ponderosa			3		
-Calamagrostis rubescens			4 **CID-4:** Cool, dry DF h.t.s	3	
-Spiraea betulifolia			4	3	
/Juniperus scopulorum	4				
/Muhlenbergia cuspidata	4				
/Physocarpus monogynus				3	
/Physocarpus malvaceus		**NID-2:** Warm, dry to moderate DF,GF,& PP h.t.s			5
-Calamagrostis rubescens	4		3		
-Pinus ponderosa			3		
-Physocarpus malvaceus	6	2			
-Pseudotsuga menziesii			5	3	
-Pachistima myrsinites				3	5
-Smilacina stellata		2			
/Carex geyeri	5 **MT-5:** Cool, dry DF h.t.s	2			
-Symphoricarpos oreophilus			4		
-Pinus ponderosa			3		
-Carex geyeri			4		

Series, h.t., c.t.	MT	NID	CID	EIWW	UTAH
/Acer glabrum					5
-Symphoricarpos oreophilus			4		
-Pachistima myrsinites				3	
-Acer glabrum			5		
/Cercocarpus ledifolius			2,4	2 **EIWW-2:** H.t.s supporting cool, dry DF forests	4 **UTAH-4:** Drier DF h.t.s
/Arnica cordifolia	5		4	2	
/Symphoricarpos oreophilus	5		2	2	4
/Viola canadensis	6 **MT-6:** Moist DF h.t.s				
/Amelanchier alnifolia	6				
/Vaccinium globulare	6	2	5 **CID-5:** Moist DF h.t.s	3	
/Linnaea borealis	6		5		
/Calamagrostis rubescens					5
-Agropyron spicatum	4,5				
-Festuca idahoensis			4		
-Pinus ponderosa	4		3		
-Arctostaphylos uva-ursi	6	2			
-Calamagrostis rubescens	6	2	4	3	
-Carex geyeri					
-Pachistima myrsinites				3	
/Juniperus communis	6,7		4	2	
/Vaccinium caespitosum	6,7	2	5		
/Arctostaphylos patula					4
/Cercocarpus montanus					4
/Quercus gambelii					4
/Berberis repens					
-Carex geyeri			3	3	4
-Pinus ponderosa					4
-Juniperus communis				3	5 **UTAH-5:** Cool or moist DF h.t.s
-Symphoricarpos oreophilus			3	2	5
-Berberis repens	4		5	3	5
-Arctostaphylos uva-ursi	4				
/Osmorhiza chilensis			5	3	5
/Cornus canadensis	7				
***Abies concolor* series**					6 **UTAH-6:** WF & BS h.t.s (mixed conifer)
***Picea pungens* series:**					
/Agropyron spicatum					6
/Berberis repens					6
/Juniperus communis					6
/Equisetum arvense					11
***Populus tremuloides* series**				4 **EIWW-4:** Aspen-dominated c.t.s	7 **UTAH-7:** Aspen-dominated h. and c.t.s

Series, h.t., c.t.	MT	NID	CID	EIWW	UTAH
***Populus tremuloides-Abies lasiocarpa* series**				4	7
***Populus tremuloides-Abies concolor* series**					7
***Populus tremuloides-Picea pungens* c.t.**					7
***Populus tremuloides-Pinus flexilis* c.t.**					7
***Populus tremuloides-Pinus ponderosa* c.t.**					7
***Populus tremuloides-Pinus contorta* series**				4	7
***Populus tremuloides-Pseudotsuga menziesii* series**				4	7
***Pinus contorta* series**	7	3 **NID-3:** H.t.s & c.t.s dominated by persistent LPP	7	5 **EIWW-5:** Persistent LPP c.t.s	8 **UTAH-8:** H.t.s with persistent LPP
***Picea* series:**					
/Senecio streptanthifolius					
-Pseudotsuga menziesii	5				
-Picea	10				
/Vaccinium caespitosum	7				
/Linnaea borealis	7,8				
/Physocarpus malvaceus	8				
/Smilacina stellata	8				
/Equisetum arvense	9				
/Clintonia uniflora	9				
/Galium triflorum	9				
/Juniperus communis	10				
***Picea engelmannii* series:**					
/Galium triflorum			9	7	
/Carex disperma			9	7	
/Equisetum arvense			9	7	11
/Arnica cordifolia				6	
/Hypnum revolutum			4	6	
/Juniperus communis				6	
/Caltha leptosepala				7	11
/Linnaea borealis				7	
/Physocarpus malvaceus				7	
/Ribes montigenum				8	12 **UTAH-12:** Cold, upper subalpine h.t.s
/Vaccinium scoparium				8	8,12

Series, h.t., c.t.	MT	NID	CID	EIWW	UTAH
/Vaccinium caespitosum					8,12
***Abies lasiocarpa* series:**					
/Vaccinium scoparium	**MT-7:** Cool h.t.s usually dominated by LPP	3			
-Calamagrostis rubescens	7		7 **CID-7:** Cool h.t.s usually dominated by LPP	6 **EIWW-6:** Mid & lower elevation subalpine forests	
-Thalictrum occidentale	8				
-Pinus albicaulis			10	8	
-Arnica latifolia					10
-Carex geyeri					10
-Vaccinium scoparium	7		7	6	8,10,12
/Vaccinium caespitosum	7	3	7		8,10
/Xerophyllum tenax					
-Vaccinium scoparium	7	4 **NID-4:** Dry, lower subalpine h.t.s	7	6	
-Vaccinium globulare	8	4	7	6	
-Coptis occidentalis		4			
-Luzula hitchcockii		4	7		
/Vaccinium globulare	7	4			10 **UTAH-10:** Dry, lower subalpine h.t.s
-Vaccinium scoparium			7	6	
-Pachistima myrsinites				6	
-Vaccinium globulare			8	6	
/Vaccinium myrtillus					10
/Pedicularis racemosa				6	10
/Berberis repens				6	10
/Symphoricarpos albus				6	
/Arnica latifolia				6	
/Thalictrum occidentale				6	
/Carex rossii				6	10
/Physocarpus malvaceus				6	10
/Osmorhiza chilensis				6	10
/Carex geyeri					10
-Pseudotsuga menziesii	8				
-Artemisia tridentata			10		
-Carex geyeri	7		7	6	
/Calamagrostis canadensis		**NID-5:** Moist, lower subalpine h.t.s		**EIWW-7:** Moist or wet SAF & ES h.t.s	11
-Vaccinium caespitosum	7	5	7	7	
-Galium triflorum	9				
-Ledum glandulosum		5	7	7	
-Ligusticum canbyi		5	9		
-Calamagrostis canadensis	9	5	7	7	
/Calamagrostis rubescens	8 **MT-8:** Dry, lower subalpine h.t.s	4	7	6	10

Series, h.t., c.t.	MT	NID	CID	EIWW	UTAH
/Clematis pseudoalpina	8				
/Arnica cordifolia	8		8 **CID-8:** Dry, lower subalpine h.t.s	6	
/Juniperus communis	10		8	6	10
/Acer glabrum			8	6	10
/Spiraea betulifolia			8	6	
/Linnaea borealis	9 **MT-9:** Moist, lower subalpine h.t.s				
-Vaccinium scoparium	7		7	6	
-Xerophyllum tenax	9		7		
-Linnaea borealis	9		8	6	
/Alnus sinuata	9		7		
/Menziesia ferruginea	9	5	9 **CID-9:** Wet or moist, lower subalpine h.t.s	7	
/Actaea rubra				7	11 **UTAH-11:** Moist to wet subalpine h.t.s
/Aconitum columbianum					11
/Clintonia uniflora	9	5	9		
/Galium triflorum	9				
/Oplopanax horridum	9				
/Caltha biflora			9		
/Coptis occidentalis			9		
/Streptopus amplexifolius		5	9	7	11
/Luzula hitchcockii	10 **MT-10:** Cold, moist upper subalpine & timberline h.t.s	6	10 **CID-10:** Cold, upper subalpine & timberline h.t.s	8 **EIWW-8:** Cold, upper subalpine & timberline h.t.s	
/Ribes montigenum	10		10		
-Trisetum spicatum					12
-Mertensiana arizonica					10
-Pinus contorta					10
-Thalictrum fendleri					10
-Pinus albicaulis				8	
-Ribes montigenum				8	10
					11 "Conifer" cover types
***Tsuga mertensiana* series:**					
/Xerophyllum tenax	8	4			
/Menziesia ferruginea	9	5			
/Clintonia uniflora		5			
/Streptopus amplexifolius		5			
/Luzula hitchcockii	10	6 **NID-6:** Upper subalpine h.t.s			

Series, h.t., c.t.	MT	NID	CID	EIWW	UTAH
***Pinus albicaulis* series**	10		10	8	
***Pinus albicaulis - Abies lasiocarpa* series**	10	6	10		
***Abies lasiocarpa - Pinus albicaulis* series**	10				
***Larix lyallii - Abies lasiocarpa* series**	10	6			
***Abies grandis* series:**	**MT-11:** Warm, moist GF, WRC, & WH h.t.s		**CID-6:** GF h.t.s		
/Physocarpus malvaceus		2			
/Spiraea betulifolia		2	6		
/Xerophyllum tenax	11	7 **NID-7:** Moderate & moist GF h.t.s	6		
/Vaccinium globulare		7	6		
/Calamagrostis rubescens			6		
/Acer glabrum			6		
/Coptis occidentalis			6		
/Clintonia uniflora		7	6		
/Linnaea borealis		7	6		
/Vaccinium caespitosum			7		
/Asarum caudatum		7			
/Senecio triangularis		7			
***Tsuga heterophylla* series:**					
/Menziesia ferruginea		5			
/Clintonia uniflora	11	8 **NID-8:** Moderate & moist WH & WRC h.t.s			
/Asarum caudatum		8			
/Gymnocarpium dryopteris		8			
***Thuja plicata* series:**					
/Clintonia uniflora		8			
/Asarum caudatum		8			
/Gymnocarpium dryopteris		8			
/Adiantum pedatum		9 **NID-9:** Very moist WRC h.t.s			
/Athyrium filix-femina		9			
/Oplopanax horridum	11	9			

[a] Habitat and community types within a series, and phases within a habitat type, are listed in this table only if they are needed to identify all members of a fire group. Community types from different geographic areas do not necessarily have identical characteristics; for precise comparisons, consult habitat type manuals.
[b] Fischer and Clayton (1983), Fischer and Bradley (1987); habitat types follow Pfister and others (1977), Roberts and Sibbernsen (1979), and Roberts (1980).
[c] This report; habitat types follow Cooper and others (1991).
[d] Crane and Fischer (1986); habitat types follow Steele and others (1981).
[e] Bradley and others (1992a); habitat and community types follow Steele and others (1983) and Mueggler (1988).
[f] Bradley and others (1992b); habitat and community types follow Mauk and Henderson (1984), Youngblood and Mauk (1985), Mueggler (1989), and Padgett and others (1989).
[g] Tree species abbreviations: PP = ponderosa pine, DF = Douglas-fir, GF = grand fir, WF = white fir, BS = blue spruce, LPP = lodgepole pine, SAF = subalpine fir, ES = Engelmann spruce, WRC = western redcedar, WH = western hemlock.

Appendix D: Scientific and Common Names of Plant Species Referred to in the Text and Appendices, and Their Abbreviations

Common names follow Patterson and others (1985); for species not in that publication, common names follow Hitchcock and Cronquist (1973) and U.S. Department of Agriculture, Soil Conservation Service (1994). List includes species from outside northern Idaho that are in appendix C.

Abbreviation	Scientific name (and synonym, if any)	Common name
	Tree Species	
ABCO	*Abies concolor*	White fir
ABGR	*Abies grandis*	Grand fir
ABLA	*Abies lasiocarpa*	Subalpine fir
BEPA	*Betula papyrifera*	Paper birch
JUSC	*Juniperus scopulorum*	Rocky Mountain juniper
LALY	*Larix lyallii*	Alpine larch
LAOC	*Larix occidentalis*	Western larch
PIEN	*Picea engelmannii*	Engelmann spruce
PIPU	*Picea pungens*	Blue spruce
PIAL	*Pinus albicaulis*	Whitebark pine
PICO	*Pinus contorta*	Lodgepole pine
PIFL	*Pinus flexilis*	Limber pine
PIMO	*Pinus monticola*	Western white pine
PIPO	*Pinus ponderosa*	Ponderosa pine
POPTRE	*Populus tremuloides*	Quaking aspen
POPTRI	*Populus trichocarpa*	Black cottonwood
PSME	*Pseudotsuga menziesii*	Douglas-fir
QUGA	*Quercus gambelii*	Gambel oak
THPL	*Thuja plicata*	Western redcedar
TSHE	*Tsuga heterophylla*	Western hemlock
TSME	*Tsuga mertensiana*	Mountain hemlock
	Shrub Species	
ACGL	*Acer glabrum*	Rocky Mountain maple
ALIN	*Alnus incana*	Thinleaf alder
ALSI	*Alnus sinuata*	Sitka alder
AMAL	*Amelanchier alnifolia*	Serviceberry
ARPA	*Arctostaphylos patula*	Greenleaf manzanita
ARUV	*Arctostaphylos uva-ursi*	Bearberry
ARNO	*Artemisia nova*	Black sagebrush
ARTR	*Artemisia tridentata*	Big sagebrush
BERE	*Berberis repens*	See *Mahonia repens*
CAME	*Cassiope mertensiana*	Mertens' mountain heather
CESA	*Ceanothus sanguineus*	Redstem ceanothus
CEVE	*Ceanothus velutinus*	Shinyleaf ceanothus
CELE	*Cercocarpus ledifolius*	Curlleaf mountain-mahogany
CEMO	*Cercocarpus montanus*	True mountain-mahogany
COCA	*Cornus canadensis*	Bunchberry dogwood
COSE	*Cornus sericea*	Red-osier dogwood
COST	*Cornus stolonifera*	See *Cornus sericea*
CRDO	*Crataegus douglasii*	Black hawthorn
	Gaultheria ovatifolia	Oregon wintergreen
HODI	*Holodiscus discolor*	Ocean-spray
JUCO	*Juniperus communis*	Common juniper
JUHO	*Juniperus horizontalis*	Creeping juniper
	Juniperus scopulorum	Rocky Mountain juniper
LEGL	*Ledum glandulosum*	Labrador tea
LIBO	*Linnaea borealis*	Twinflower
LOUT	*Lonicera utahensis*	Utah honeysuckle
MARE	*Mahonia repens*	Creeping Oregon grape
MEFE	*Menziesia ferruginea*	Fool's huckleberry

(con.)

Appendix D (Con.)

Abbreviation	Scientific name (and synonym, if any)	Common name
OPHO	*Oplopanax horridum*	Devil's club
PAMY	*Pachistima myrsinites*	Pachistima
PHLE	*Philadelphus lewisii*	Syringa
PHEM	*Phyllodoce empetriformis*	Red mountain-heather
PHMA	*Physocarpus malvaceus*	Mallow ninebark
PHMO	*Physocarpus monogynus*	Mountain ninebark
PREM	*Prunus emarginata*	Bitter cherry
PRVI	*Prunus virginiana*	Common chokecherry
PUTR	*Purshia tridentata*	Antelope brush
RHAL	*Rhododendron albiflorum*	White rhododendron
RICE	*Ribes cereum*	Wax currant
RILA	*Ribes lacustre*	Prickly currant
RIMO	*Ribes montigenum*	Gooseberry currant
RIVI	*Ribes viscosissimum*	Sticky currant
ROGY	*Rosa gymnocarpa*	Baldhip rose
ROWO	*Rosa woodsii*	Pearhip rose
RUPA	*Rubus parviflorus*	Western thimbleberry
SASC	*Salix scouleriana*	Scouler willow
SARA	*Sambucus racemosa*	Elderberry
SHCA	*Shepherdia canadensis*	Buffaloberry
SOSC	*Sorbus scopulina*	Mountain-ash
SPBE	*Spiraea betulifolia*	Spiraea
SYAL	*Symphoricarpos albus*	Common snowberry
SYMO	*Symphoricarpos mollis*	Creeping snowberry
SYOC	*Symphoricarpos occidentalis*	Western snowberry
SYOR	*Symphoricarpos oreophilus*	Mountain snowberry
TABR	*Taxus brevifolia*	Pacific yew
VACA	*Vaccinium caespitosum*	Dwarf huckleberry
VAGL	*Vaccinium globulare*	Blue huckleberry
VAME	*Vaccinium membranaceum*	Big huckleberry
VAMY	*Vaccinium myrtillus*	Dwarf bilberry
VASC	*Vaccinium scoparium*	Grouse whortleberry
	Grassy species	
AGSP	*Agropyron spicatum*	See *Pseudoroegneria spicata*
	Agrostis spp.	Bentgrass species
	Andropogon spp.	Bluestem species
	Bromus inermis	Smooth brome
	Bromus tectorum	Cheatgrass
BRVU	*Bromus vulgaris*	Columbia brome
CACA	*Calamagrostis canadensis*	Bluejoint reedgrass
CARU	*Calamagrostis rubescens*	Pinegrass
CACO	*Carex concinnoides*	Northwestern sedge
CADI	*Carex disperma*	Softleaf sedge
CAGE	*Carex geyeri*	Elk sedge
CARO	*Carex rossii*	Ross sedge
CILA	*Cinna latifolia*	Drooping woodreed
	Dactylis spp.	Orchard-grass species
DEAT	*Deschampsia atropurpurea*	Mountain hairgrass
	Elymus spp.	Wildrye species
FEID	*Festuca idahoensis*	Idaho fescue
FESC	*Festuca scabrella*	Rough fescue
	Festuca viridula	Greenleaf fescue
JUPA	*Juncus parryi*	Parry's rush
	Koeleria cristata	Junegrass
LUHI	*Luzula hitchcockii*	Smooth woodrush
MUCU	*Muhlenbergia cuspidata*	Plains muhly

(con.)

Appendix D (Con.)

Abbreviation	Scientific name (and synonym, if any)	Common name
MUMO	*Muhlenbergia montana*	Mountain muhly
	Phleum pratense	Common timothy
	Poa spp.	Bluegrass species
PSSP	*Pseudoroegneria spicata*	Bluebunch wheatgrass
STOC	*Stipa occidentalis*	Western needlegrass
TRSP	*Trisetum spicatum*	Spike trisetum
	Forbs	
	Achillea lanulosa	Fernleaf yarrow
ACMI	*Achillea millefolium*	Common yarrow
ACCO	*Aconitum columbianum*	Monkshood
ACRU	*Actaea rubra*	Baneberry
ADBI	*Adenocaulon bicolor*	Trail-plant
ADPE	*Adiantum pedatum*	Maidenhair fern
	Agoseris spp.	False-dandelion species
ANMA	*Anaphalis margaritacea*	Pearly everlasting
ANPI	*Anemone piperi*	Windflower
	Antennaria spp.	Pussy-toes species
ARNU	*Aralia nudicaulis*	Wild sarsaparilla
ARMA	*Arenaria macrophylla*	Bigleaf sandwort
ARCO	*Arnica cordifolia*	Heartleaf arnica
ARLA	*Arnica latifolia*	Mountain arnica
ASCA	*Asarum caudatum*	Wild ginger
ASCO	*Aster conspicuus*	Showy aster
	Astragalus canadensis	Canadian milkvetch
ATFI	*Athyrium filix-femina*	Ladyfern
BASA	*Balsamorhiza sagittata*	Arrowleaf balsamroot
	Botrychium virginianum	Grape fern
BOMA	*Boykinia major*	Mountain boykinia
CABI	*Caltha biflora*	White marshmarigold
CALE	*Caltha leptosepala*	White marshmarigold
	Centaurea maculosa	Spotted knapweed
CHUM	*Chimaphila umbellata*	Prince's pine
	Chrysanthemum spp.	Chrysanthemum species
CIAL	*Circaea alpina*	Alpine circaea
	Cirsium spp.	Thistle species
CLPS	*Clematis pseudoalpina*	Rock clematis
CLUN	*Clintonia uniflora*	Queencup beadlily
	Conyza spp.	Conyza species
COOC	*Coptis occidentalis*	Western goldthread
COCA	*Cornus canadensis*	Bunchberry dogwood
DIHO	*Disporum hookeri*	Hooker fairy-bell
DOJE	*Dodecatheon jeffreyi*	Jeffrey's shooting star
	Dryopteris austriaca	Mountain woodfern
	Dropteris filix-mas	Male fern
EPAN	*Epilobium angustifolium*	Fireweed
EQAR	*Equisetum arvense*	Field horsetail
	Erigeron spp.	Daisy, fleabane species
ERGR	*Erythronium grandiflorum*	Dogtooth-violet
	Fragaria vesca	Woods strawberry
FRVI	*Fragaria virginiana*	Strawberry
GABO	*Galium boreale*	Northern bedstraw
GATR	*Galium triflorum*	Sweetscented bedstraw
GEBI	*Geranium bicknellii*	Bicknell's geranium
	Gnaphalium spp.	Everlasting species
GOOB	*Goodyera oblongifolia*	Rattlesnake-plantain

(con.)

Appendix D (Con.)

Abbreviation	Scientific name (and synonym, if any)	Common name
GOOB	*Goodyera oblongifolia*	Rattlesnake-plantain
GYDR	*Gymnocarpium dryopteris*	Oak-fern
	Habenaria spp.	Orchid species
HECY	*Heuchera cylindrica*	Roundleaf alumroot
	Hypericum perforatum	Common St. John's-wort
HYRE	*Hypnum revolutum*	Hypnum
ILRI	*Iliamna rivularis*	Streambank globemallow
	Lactuca spp.	Lettuce species
LICA	*Ligusticum canbyi*	Canby's licorice-root
LICO	*Listera convallarioides*	Broad-lipped twayblade
	Lupinus argenteus	Silvery lupine
LYAM	*Lysichitum americanum*	Skunk cabbage
MEAR	*Mertensia arizonica*	Aspen bluebells
MEPA	*Mertensia paniculata*	Tall bluebells
MIBR	*Mitella breweri*	Brewer's mitrewort
	Mitella stauropetala	Side-flowered mitrewort
	Montia spp.	Miner's lettuce
OSCH	*Osmorhiza chilensis*	Mountain sweet-cicely
	Pedicularis racemosa	Leafy lousewort
	Plantago spp.	Plantain species
	Polemonium pulcherrimum	Jacob's-ladder
POMU	*Polystichum munitum*	Western swordfern
	Potentilla spp.	Cinquefoil species
PTAQ	*Pteridium aquilinum*	Bracken fern
PYAS	*Pyrola asarifolia*	Common pink wintergreen
	Pyrola picta	Whiteveined wintergreen
PYSE	*Pyrola secunda*	One-sided wintergreen
RUOC	*Rudbeckia occidentalis*	Western coneflower
	Rumex spp.	Dock species
	Senecio serra	Butterweed groundsel
SETR	*Senecio triangularis*	Arrowleaf groundsel
SEST	*Senecio streptanthifolius*	Cleftleaf groundsel
SMRA	*Smilacina racemosa*	False Solomon's seal
SMST	*Smilacina stellata*	Starry Solomon-seal
	Solidago spp.	Goldenrod species
	Sonchus spp.	Sow-thistle species
	Stellaria crispa	Curled starwort
STAM	*Streptopus amplexifolius*	Twisted-stalk
SYPL	*Synthyris platycarpa*	Evergreen synthyris
	Tanacetum spp.	Tansy species
	Taraxacum spp.	Dandelion species
THFE	*Thalictrum fendleri*	Fendler's meadowrue
THOC	*Thalictrum occidentale*	Western meadowrue
TITR	*Tiarella trifoliata*	Coolwort foamflower
	Tragopogon spp.	Salsify
TRCA	*Trautvetteria caroliniensis*	False bugbane
	Trifolium spp.	Clover species
TROV	*Trillium ovatum*	White trillium
VASI	*Valeriana sitchensis*	Sitka valerian
VEVI	*Veratrum viride*	American false hellebore
VICA	*Viola canadensis*	Canadian white violet
VIGL	*Viola glabella*	Pioneer violet
VIOR	*Viola orbiculata*	Round-leaved violet
XETE	*Xerophyllum tenax*	Beargrass

Smith, Jane Kapler; Fischer, William C. 1997. Fire ecology of the forest habitat types of northern Idaho. Gen. Tech. Rep. INT-GTR-363. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Research Station. 142 p.

Provides information on fire ecology in forest habitat and community types occurring in northern Idaho. Identifies fire groups based on presettlement fire regimes and patterns of succession and stand development after fire. Describes forest fuels and suggests considerations for fire management.

Keywords: forest fire, fire management, forest fuels, forest succession, fire effects

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The Intermountain Research Station provides scientific knowledge and technology to improve management, protection, and use of the forests and rangelands of the Intermountain West. Research is designed to meet the needs of National Forest managers, Federal and State agencies, industry, academic institutions, public and private organizations, and individuals. Results of research are made available through publications, symposia, workshops, training sessions, and personal contacts.

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